POINT TO POINT

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Points of view

THE OVERALL PERFORMANCE between any two subscribers on a telephone system is largely governed by economic considerations. Within a given economic framework, the division of expenditure among the various constituent parts of the telephone network is rather less arbitrary. The normal, and undoubtedly correct, approach is to allocate the lowest performance to the equipment most widely used. This results in standards for the subscriber and local exchanges closely related to the overall system performance.

So far as is known, the only criterion for subscriber to subscriber performance is that of the C.C.I.F, which quotes a maximum permissible overall transmission loss of 40 dB, allocated as 18 dB at the sending end and 13 dB at the receiving end.[1] The circuit quality as such is specifically excluded, and experience suggests that signal-to-noise ratios at the subscriber much in excess of 25 to 30 dB are not expected.

Once the subscriber and local exchange aspects of the network have been fixed, the performance of junction and trunk circuits has to be decided. This is not always a function of economics, and may be dictated by the performance of available equipment. When, in the 1930s, the first carrier equipment became available, it was stipulated that trunk circuit performance should not degrade the subscriber to subscriber performance, in order not to upset the investment in the local networks. In practice, this performance could easily be attained for physical wire circuits using relatively small numbers of channels.

As the international network extended throughout Europe, so trunk circuit performances were upgraded to maintain the criterion of negligible effect on overall circuit quality. This led to performance objectives of a very high order, largely related to underground cable

networks. When multichannel radio links became available, the tendency was merely to regard radio as an alternative to line, and therefore to expect the same performance irrespective of any limitation which the medium imposed.

It is doubtful whether any of the underground cable networks in Europe are maintained to the recommended C.C.I.F performance standards. Likewise for radio, despite heavy expenditure, it is only recently that equipment fully complying with the latest C.C.I.R recommendations has become available, and the difficulty of meeting these performance specifications is such that equipment is unlikely to have sufficient margin to enable the full C.C.I.R performance to be maintained economically.

It has long been recognized that it is not economical (although technically feasible) to meet C.C.I.R recommended performance for tropospheric scatter services. On long distance cables, for economic reasons, channel spacing has been reduced from 4 kc/s to 3 kc/s, and time-sharing arrangements are doubling the number of channels available, all of which will affect the overall performance which is obtained. Already studies indicate that it is unlikely to be practical to engineer satellite communication circuits to meet C.C.I.R performance recommendations.

With improvements in telephone instruments and the growth of the telephone network, the sending transmission loss will rarely come up to the permitted maximum of 18 dB, and transmitted speech quality will be better than originally anticipated. Even if trunk circuits are not fully up to the recommended performance, the overall system performance is probably better than the minimum expected, for this reason. A far greater degree of overall reliability and a more economical circuit would probably be obtained by recognizing this fact. A reduction in trunk circuit performance of about 6 dB would bring the C.C.I.R figures into line with North American toll practice, used for the Bell telephone system, providing highly satisfactory long-distance trunk circuit performance. Such a relaxation would probably enable tropospheric scatter circuits to be engineered in conformity with the new recommendations and therefore permit their full integration into the system

as regular, rather than sub-standard, circuits. This more realistic assessment of trunk circuit performance would be more in keeping with that which could be expected for satellite communication circuits.

This could be done without degradation to the overall subscriber to subscriber performance in the majority of cases. Where, in more sparsely populated areas, sending transmission loss utilizes the full 18 dB allowed (and probably a good deal more) then every measure should be sought to bring these circuits into line rather than to make the whole of the remainder of the network significantly better than necessary. One possibility would be to utilize a much simplified form of constant volume amplifier for such circuits to bring up the level at the 4-wire input to the trunk system.

As has already been said, present performance levels appear to be very close to that which is technically attainable at the present time. Production equipment should incorporate a performance margin to allow for gradual performance degradation due to valve ageing, circuit misalignment, etc, in order to assure satisfactory long-term equipment reliability. It is doubtful if this exists at present.

We are now at the formative stage for equipment which will provide much of the future trunk network, whether it be repeatered submarine coaxial circuits or by one of the several solutions using radio. A reappraisal of the system performances established before any of these media had become available on a wide scale would be appropriate, and should be made in the light of present-day circumstances.

A.J.W.

Reference

1 C.C.I.F XVIIIth Plenary Assembly (Geneva, 1956), Vol. III bis, Part I, Section 1, p.25.

A Note on Satellite Communications

M. TELFORD, B.Sc(Eng), A.M.I.E.E

This short article surveys the situation brought about by the successful launching of the project 'Echo' passive reflector satellite, and discusses the steps that should be taken to bring about orderly exploitation of the communication potentialities using satellites.

AT PRESENT the virtual monopoly of intercontinental telephone communication and the large share of telegraphic communication held for thirty years by HF radio services is being strongly threatened by trans-oceanic wideband cable systems. Although cable systems involve a large capital outlay, their traffic capacity (cables with up to 128 speech channels are being planned) and the high standards of quality that may be attained, make it virtually certain that all trunk telephone traffic between the major land masses will be taken away from HF radio during the next 10—20 years. The crowded state of the 3—30 Mc/s spectrum, already giving rise to extensive mutual interference between different services (which is certain to be accentuated during the forthcoming sunspot minimum period) means that there is no chance of ionospheric propagation providing a technical alternative to the cable as far as the heavily loaded trunk routes are concerned.

The only possibility that can be foreseen at present of redressing the balance in favour of radio is by the use of earth-satellite systems. The comparatively recent, but intensive, study of these has shown that two main types of system are possible, using active and passive repeaters respectively. The latter type has already met with experimental success, with the placing in orbit of the Project Echo balloon reflector. However, even with a transmitter power of 10 kW and the use of large aerials at both ends of the link, the present capacity of the communication system

using Echo is one intermittent speech channel over a distance of 3 000 miles. No doubt this can be substantially increased but the likelihood of obtaining large traffic capacity economically is not very great. In view of the fact that attenuation over the path between the earth and the satellite reflector must be allowed for twice, it is inevitable that extremely costly ground station equipment will be necessary. It has been estimated, for example, that a transmitter power of 100 kW and dishes of 150 foot diameter (at both ends) will be required to achieve a 40 dB S/N ratio in a 5 Mc/s baseband for transatlantic communication, using a balloon reflector of 100 foot diameter in an orbit of 3 000 miles' height. These calculations assumed the ultimate performance possible from presently known FM receiver techniques. The successful operation of such a system would involve at least duplication of the ground equipment in order to follow the passes of successive satellites without breaks in communication. A system employing passive satellites in 24 hour equatorial orbit, at an elevation of approximately 22 000 miles, would require an additional gain of some 34 dB, for the same performance.

Turning to the active satellite case, it may be shown that a similar result would be obtained by radiating about 1 watt from an omnidirectional aerial on a satellite and receiving it via a 60 foot dish aerial, under the same physical conditions and with the same assumptions as to the modulation method and receiving techniques as were quoted in the passive case. In the reverse direction the overall noise factor of the satellite receiving system would inevitably be greater than that of the ground station; it is also reasonable to assume that it will not at first be possible to use complex receiving techniques giving ultimately attainable performance on the satellite. Nevertheless, a ground transmitter power of 1 kW is likely to be adequate. It can be stated with complete confidence that the radio equipment necessary for an efficient active satellite repeater system, of comparable performance and traffic capacity to current microwave link and overland cable systems, is within the reach of present techniques. There are many problems of detailed design, however, particularly those connected with component life and provision of power supplies on the satellite, which will require intensive study and research before an economical and reliable engineering solution is found.

The problems connected with frequency allocation, bandwidth utilization and mutual interference with other services are interwoven and will assume major importance.

The estimates of system parameters given above were based on a wide deviation FM system, needing an RF bandwidth of greater than 100 Mc/s per path in order to obtain the necessary quality for transmission of 600 speech channels or 1 television channel. The system frequency allocation would need to be about 500 Mc/s in the active case and 250 Mc/s in the passive case (i.e approximately 800 kc/s and 400 kc/s respectively per two-way speech channel). Alternative modulation systems of greater efficiency are possible—Pulse Code Modulation, for example, appears to offer the possibility of similar or better performance in less than one-third of the bandwidth. Nevertheless, the question must be asked whether the allocation of such large blocks of spectrum space, even to heavily loaded communications systems of first importance, will be possible or is in fact justified.

Cosmic noise and atmospheric absorption limit the usable band of frequencies for satellite point-to-point systems to about 500—20 000 Mc/s and the portion in which most efficient operation may be obtained to 1 000—10 000 Mc/s. Many other services occupy this band at present, and their use of it is likely to increase rapidly. The low level of utilizable signal in the ground receiver of a satellite system, and in many other types of modern microwave receiver designed for high sensitivity, increases their susceptibility to interference and implies that severe restrictions will have to be imposed on joint utilization of spectrum space by different stations and services. It is unlikely that satellite repeaters will use highly directional aerial systems for a long time—the probability is that they will illuminate the whole of the visible area of the earth below them with a field which may be of sufficiently high level to degrade the performance of other microwave services operating on the same frequency. Effective frequency allocation procedures can alleviate the problem but will have to be truly international. The conclusion may well be drawn that something more must be done.

The most effective answer would seem to lie in the intelligent use of information and modulation theory, in particular of bandwidth and time

compression techniques. It was, for example, demonstrated more than 20 years ago that intelligible speech may be relayed in a bandwidth of less than 300 c/s, yet the amount of effort put into improving this technique to a point where it can be commercially applied has been negligible, when compared with that devoted to many less worthy causes. The time is with us when such effort is essential, if radio-communications systems in the widest sense are not to submerge themselves in a welter of self-generated noise. The responsibility for this does not rest only with satellite system designers and users—nearly all forms of radio-system use highly redundant methods of information transmission. It may be argued that the equipment required will be complex and costly to design and produce. This is true, but the capital investment required will be trifling compared with that of the systems as a whole. The rewards are high and there may be no other solution.

There is little doubt that satellite communications systems are feasible. Their economics will probably compare favourably with those of cable and other long-distance systems, and the traffic capacity they can provide will be utilized. The number of telephones in the world has approximately doubled during the last 10 years from some 70 to 140 millions and more than half of these are in the United States. Overseas telephone messages have, in the U.S.A, increased from one million to four million calls per year over the same period. The world potentiality has scarcely been touched. Data transmission is in its infancy, intercontinental television transmission does not exist. If satellite communication potential is to be exploited to the full then a concerted immediate effort by Governments, operating companies and private manufacturing and research organizations is essential. The time is not available for effort to be squandered in duplicate research projects and inter-organizational rivalries. A planned programme must be laid down, deciding, first, on what projects are most favourable, and what their timing should be. The research, development and manufacturing effort must be divided, to the maximum possible mutual advantage and with the fullest sharing of the knowledge gained. On the radio side the broad areas of ground station transmitting and receiving equipment, aerial and tracking systems, modulation systems and satellite radio equipment

may be too wide for any one organization to cope with alone, with the necessary speed. There is every advantage to be gained also from the highest possible degree of system standardization and our fundamental knowledge is surely adequate to allow of this. The same considerations no doubt apply to the launching and satellite vehicles, with their associated propulsion and electrical power facilities.

Finally, this is not the problem of one country or one continent alone. Machinery for international collaboration in the sensible design and use of communications facilities has been painfully built up throughout this century and must be fully utilized. In a more limited way there would be obvious economies in channelling the communications requirements of Western Europe, for example, with other continents via a relatively few selected centres.

M. TELFORD, born in Liverpool 1924. Studied Electrical Engineering at Birmingham University and took his war degree in 1944. With Admiralty Signals Establishment 1943-46 on design work connected with the development of D/F equipment. Returned to Birmingham University 1946 where he took an honours degree in Electrical Engineering. In 1947, he joined A. C. Cossor Ltd, in their Television Development Laboratories.

Subsequently taught Mathematics and Physics in the Belfast High School and College of Technology from 1948-51. He joined M.W.T in 1951 as a Development Engineer and was engaged on HF power transformer and VHF high power filter development. In 1955 he transferred to Communications Division as assistant to the Chief Communications Engineer and is now technical adviser to the Manager of the Division, and joint editor of *Point to Point Telecommunications*.

Points at Issue

We reproduce extracts from correspondence between Mr Walter Lyons, of R.C.A Communications Inc, and Messrs J. V. Beard and A. J. Wheeldon, authors of the article 'A Comparison between Alternative HF Telegraph Systems' which appeared in Point to Point Telecommunications, *Vol. 4, No. 3, June 1960.*

FROM MR WALTER LYONS (21.7.60)

'OF PARTICULAR INTEREST was your comparison of phase and frequency modulation. Your unique method of assessment of the several types of modulation was, I feel, a large contribution.

On the other hand, in the interests of better understanding and co-operation between global communicators, I would like to point out certain exceptions that I have to your conclusions, especially in regard to FSK.

Recognizing multipath delay distortion on long haul circuits to be of the order of 3 to 3·5 milliseconds:

(1) It is desirable to limit the element duration to not less than 10 milliseconds.

(2) Since, at this speed, we require little protection against multipath delay distortion, sine wave keying may be used.

(3) Under these conditions, the bandwidth may be reduced to a minimum to accommodate such keying and provide adequate cross-talk protection. For this to be comparable in practice to A1, only first order sidebands may be passed.

(4) As above, the elimination of second order keying side frequencies will introduce intolerable distortion at indices above unity. Therefore, the choice of an index of 0·7 to 0·8 seems to be desirable—

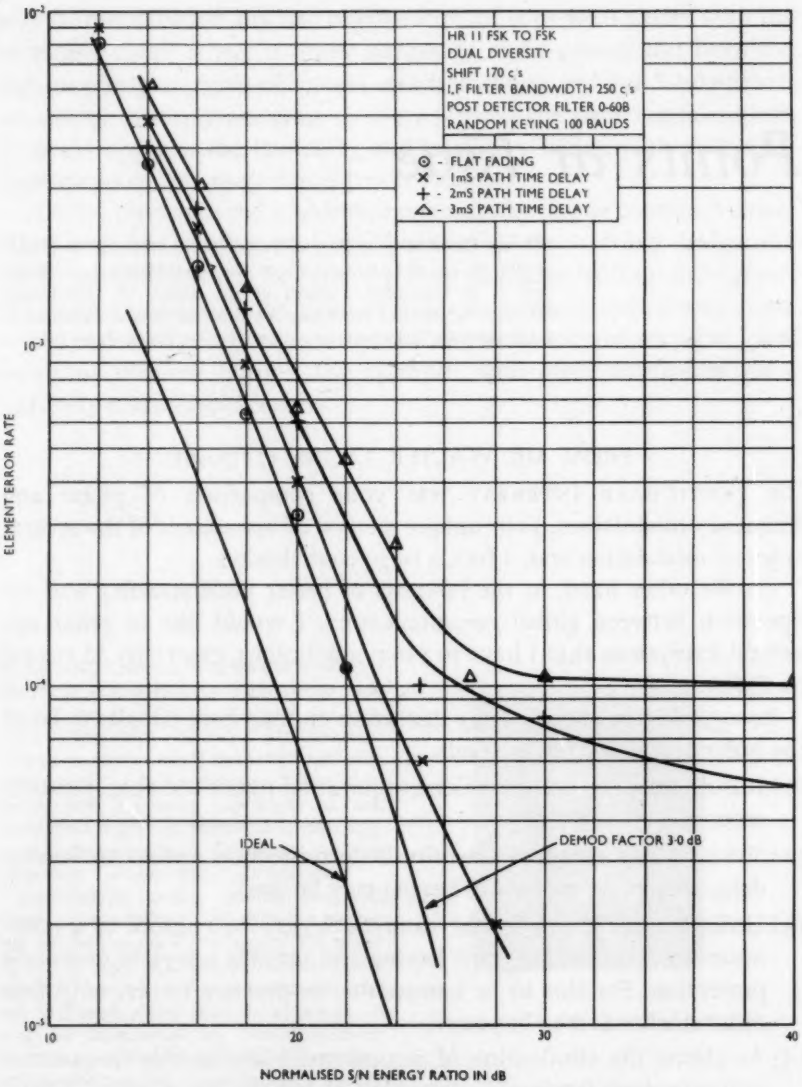

Fig.1. Effect of path time delay on receiver performance

this has been borne out in experimental trials in addition to theoretical studies.

(5) The result of implementing (4) above is the reduction of selective fading effects for this small difference between mark and space frequencies, so that Assessor techniques (Law) would be out of consideration.

(6) The Nyquist efficiency of this system, as applied to transatlantic cable operation, is approximately 42%, the highest attainable for FSK to date, and not too far under the predicted 65% figure for quadrature phase modulation, which is too unreliable to use on commercial HF radio circuits.

(7) Comparative tests on long haul circuits, e.g. Tangier/New York and San Francisco/Tokyo, have shown a minimum error rate improvement of 3 to 1, and an unmentionably much higher improvement under conditions of high multipath delay in favour of the system above described (100 baud, 80 cps shift, sine wave keying) in comparison to 200 baud FSK of modulation index 2·0.'

FROM THE AUTHORS (25.8.60)

'Commenting on your points in order:

(1) We are pleased to note that you feel that multipath delay distortion on long haul circuits frequently exceeds 2 to 3 m/secs. This is our view but it does not appear to be universally shared.

(2) We agree that sine wave keying should be used on any system in which optimum bandwidth utilization is required. This has not always been the case in the past with single channel FSK.

(3) Your comment (3) follows logically from (2).

(4) We are afraid that we do not fully understand your argument under this head. As the modulation index is increased above unity the bandwidth will necessarily increase and the filter characteristic will be such as to admit harmonics of the keying frequencies, and, therefore, the situation that would arise were sine wave keying to be used, is not truly relevant. Our own experience, starting from relatively high modulation indices and working downwards, is that under con-

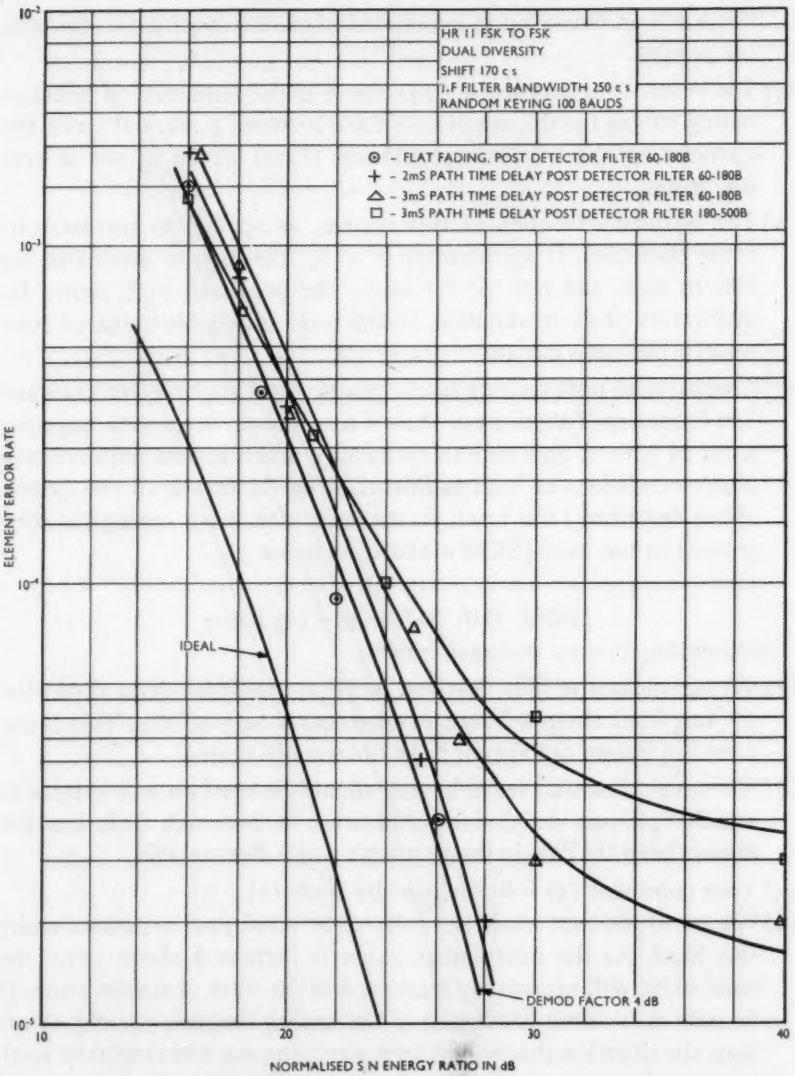

Fig.2. Effect of path time delay on receiver performance

ditions of selective fading (which provides the most difficult conditions of operation), a reduction in frequency shift results in a minimum error rate irrespective of input signal-to-noise ratio, Figs.1, 2 and 3 indicate that even with a modulation index of 1·7, one suffers this condition when path time delay rises to 3 m/secs. We have no experimental evidence for modulation indices below 1·7, but would have expected that this situation would have worsened.

(5) We agree with your comment that when the frequency shift is very small, then the amplitude difference under selective fading conditions will be reduced, but the differential path time delay will remain, and it is this problem, it seems to us, which gives rise to the greatest difficulty. Law purposely chose separations between mark and space frequencies which gave the maximum differential amplitude for mark and space signals in order to obtain frequency diversity, and when this is used for multi-channel telegraphy this produces no bandwidth penalty.

(6) We feel that for a stable propagation medium such as cable, bandwidth efficiency will probably be the most important single factor. It is only when equipment having optimum bandwidth utilization proves incapable of coping with the unstable propagating medium, that one would depart from this criterion. For this reason we feel it unlikely that any single equipment will be equally suited to line or cable use and for use over HF radio circuits.

(7) We would not dispute this comment but feel that HF telegraphy has frequently been bedevilled by comparative tests in which more than one variable is involved. In the tests which you report both the modulation index and the traffic speed have been altered and the improvement could be due to either or both, or a combination of these factors.'

FROM MR WALTER LYONS (30.8.60)

'To explain further my (4) of 21.7.60, I refer to the second order Bessel function components of a sine wave which are a factor in indices of unity or higher, requiring twice the width to avoid distortion. Fractional

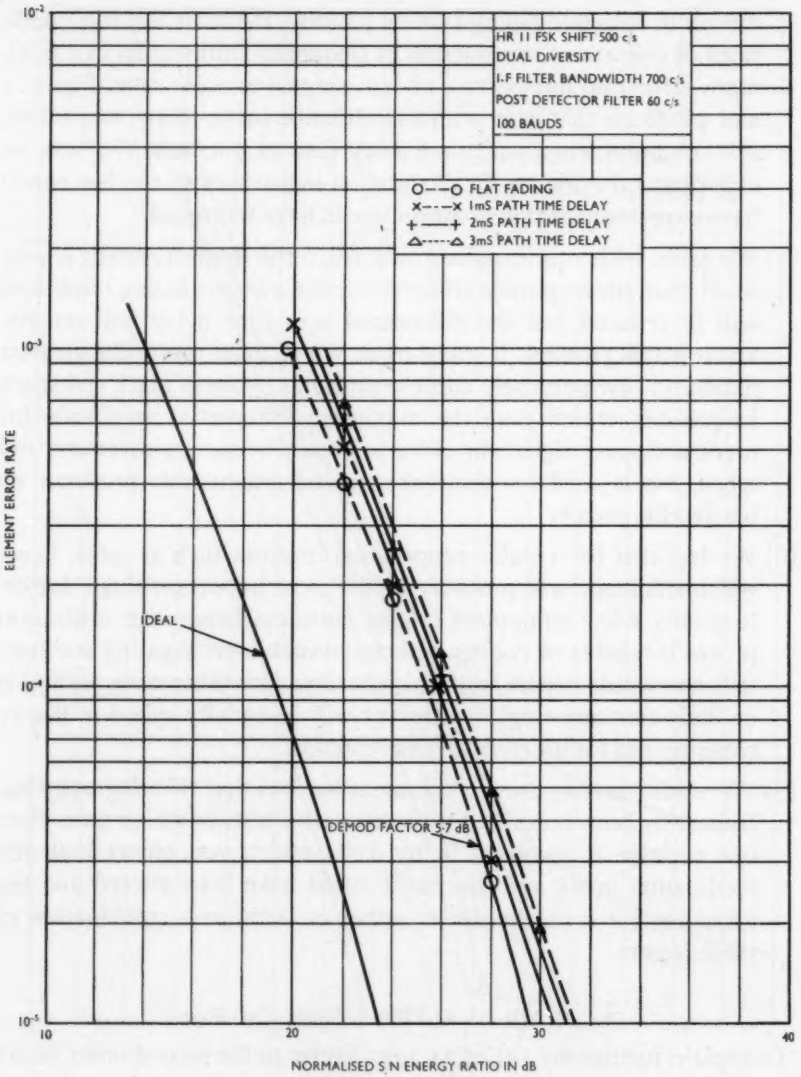

Fig.3. Effect of path time delay on receiver performance

index of modulation therefore allows for narrow IF filters and less noise.

(5) It has been established by researchers that auto-correlation in multipath time delay exists for substantial time. It has also been established that the greater the frequency separation, the lower the correlation between signals both as to fading and multipath time delay, which is concomitant. Hence, by reducing the shift we reduce the difference in multipath time delay difference between 'mark' and 'space' and reduce signal element distortion especially if synchronous receiving means are applied. For this reason, I have stated that 'Assessor techniques (Law) would be out of consideration', since we would be buying more bandwidth and complication in equipment without any compensating improvement over fractional deviation ratio FSK. My paper in 'Electrical Engineering' for February 1960, page 146, may be of interest in this regard.

(6) I agree with your comments on this item. It is for this reason that we proposed channel separations of 120 cps on cable and 170 cps on radio to handle 100 baud. By reducing the system distortion using wider channelling we can tolerate higher fortuitous distortion due to the unstable propagation by radio.

(7) I admit the two variables but the objective of the test was the comparison of two systems and for this reason I feel the test is quite valid. I should point out at this time that because 200 baud keying suffers more by reason of its shorter keying element, it requires more square keying (at least the third harmonic) for protection against multipath delay distortion. The longer keying element of 100 baud traffic does not require such protection and we therefore can take advantage of sine wave keying and fractional modulation index (0·8) to reduce our bandwidth to a minimum which will, surprisingly, reduce the required normalized S/N on HF circuits. We should remember here that we are dealing with impulse rather than Gaussian noise.

I hope that we now understand each other and that publication of this correspondence will serve to bring about better co-operation between international communicators.'

Remote Presentation of Radar Information

G. N. S. TAYLOR, B.A

1 INTRODUCTION

LONG RANGE SURVEILLANCE RADAR is used by both civil aviation authorities and military air forces. The former use radar to ensure the safety of civil aircraft and the efficient flow of air traffic, while the latter are primarily concerned with the detection of hostile aircraft and missiles and their interception by defensive weapons. Broadly speaking, while the military authorities are trying to bring aircraft together, their civil counterparts are trying to keep them apart. The problems of the radar itself and its deployment are, however, fairly similar for both types of user.

The simplest radar system can be divided into two parts, the data-gathering section and the display section. The former section, often called the aerial head, consists of the aerial, transmitter and receiver, while the latter can be either a plan position indicator or a height display. In recent years a further section has developed, that concerned with data processing, and this fits between the first two.

In some cases it is possible to locate the aerial head near the display section. This is organizationally ideal, as it simplifies administrative and technical control but, increasingly, with the greater use of radar, it is becoming necessary to separate these two sections and locate them each where they can be used most efficiently.

An operations room, housing the display section, whether for civil air traffic control or military control and reporting, must be located at the

centre of a network of landline, radio and other communications. The radar station must be sited high above local obstructions, such as buildings and hills, if it is to provide long range detection and radar cover down to low angles of elevation. It often happens that a radar picture is required from more than one remotely-sited radar station or the picture from the same radar may be required in more than one operations room. It is therefore necessary to be able to transmit radar information from a remote site as accurately and as rapidly as possible.

2 THE REQUIREMENT

Video signals at the output from a primary surveillance radar require a bandwidth of between about 0·25 and 2·0 Mc/s to avoid deterioration; secondary radar signals require up to 3·5 Mc/s to maintain pulse definition. However, there is a large amount of redundancy in a radar picture and various systems have been devised in attempts to reduce the bandwidth required.

Of these methods the most practical are the encoding system and the storage system. The encoding system is complex and involves conversion of the basic signals (which are in analogue form) into digital form, and then establishing the presence of aircraft tracks by sorting this information in terms of relative positions and velocities and rejecting those above and below predetermined limits. The cartesian co-ordinates of the aircraft echoes are then transmitted by landline or narrow band radio link. The required bandwidth can be as low as that of a single speech channel. This system is very elegant but requires a large amount of equipment at each radar station. It is doubtful whether a landline would be considered secure enough for military use. When the cost of the encoding equipment is added to the landline rental charge the system would not be very economical for civil air traffic control.

The storage system is simpler and in one method consists of writing the radar picture on a storage matrix in a cathode ray tube and then reading it off at a slower rate with another electron beam. The bandwidth required to transmit the picture from the tube is determined by the rate of the readout, but it is generally too great for transmission over a normal speech channel and specialized communications links must be used.

An alternative approach is to transmit the radar video signals directly without any prior processing beyond that normally applied after the receiver. A fairly wide bandwidth is required but by using the microwave communications bands this is easily achieved. The use of microwaves has the added advantage that narrow beamwidths are easily obtained and both military security and freedom from external interferences are readily achieved.

From the radar point of view it is desirable to keep the amount of equipment at the aerial head as small as possible, partly in order to reduce the need for staff on remote sites and also to improve reliability. In practice the use of wideband microwave links has proved very suc-

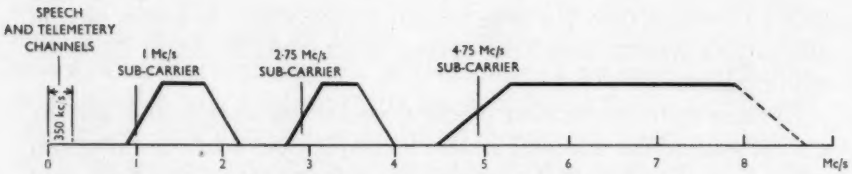

Fig.1a. Baseband arrangement for radar data link

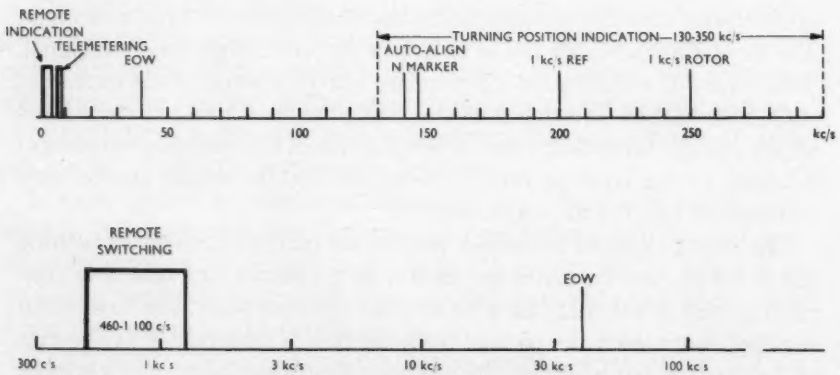

Fig.1b. Baseband arrangement for reverse control link

cessful, and as a result remote radar stations have already been designed for unattended operation. There are also considerable economic advantages in the wideband system. The use of multi-head radars demands the simultaneous transmission of several video channels, and often a secondary radar channel as well; a microwave link system, provided it has been designed with a wide bandwidth capability, can transmit more than one video channel with very little increase in cost. By using travelling wave tubes with their inherently wideband characteristics the cost of this bandwidth is not high. In addition, the use of non-demodulating travelling wave tube repeater stations leads to a very reliable transmission system.

It is usually necessary to transmit further information such as instantaneous aerial position, North marker indication, meter readings, indicator lamp circuits, the instantaneous angle of elevation of a nodding height finder aerial, ADF signals (in cases where the DF equipment is sited near the radar) and at least one speech channel. If a VHF air/ground receiving station is located near the radar site, additional speech channels will also be required on the link.

In some circumstances a reverse link is necessary to provide for remote control of the radar equipment to transmit voice modulation for VHF air/ground communication transmitters at the radar site, and for one or more reverse speech channels for intercommunication between the radar site and the operations centre. The reverse link need only have a comparatively narrow bandwidth as no wideband information is transmitted over it. The reverse link radio frequency will differ from that of the forward link but, provided they are in the same frequency band, common aerial working may be employed.

3 A TYPICAL SYSTEM

Fig.1 shows the baseband frequency arrangement for a typical microwave radar link. The equipment operates in the 4 000 Mc/s band, and carries simultaneously two 1 Mc/s primary radar channels and one 3 Mc/s secondary radar channel. Synchronizing pulses for the radar are carried on one of the radar channels by using positive modulation for the video signals and negative modulation for the sync. A turning channel

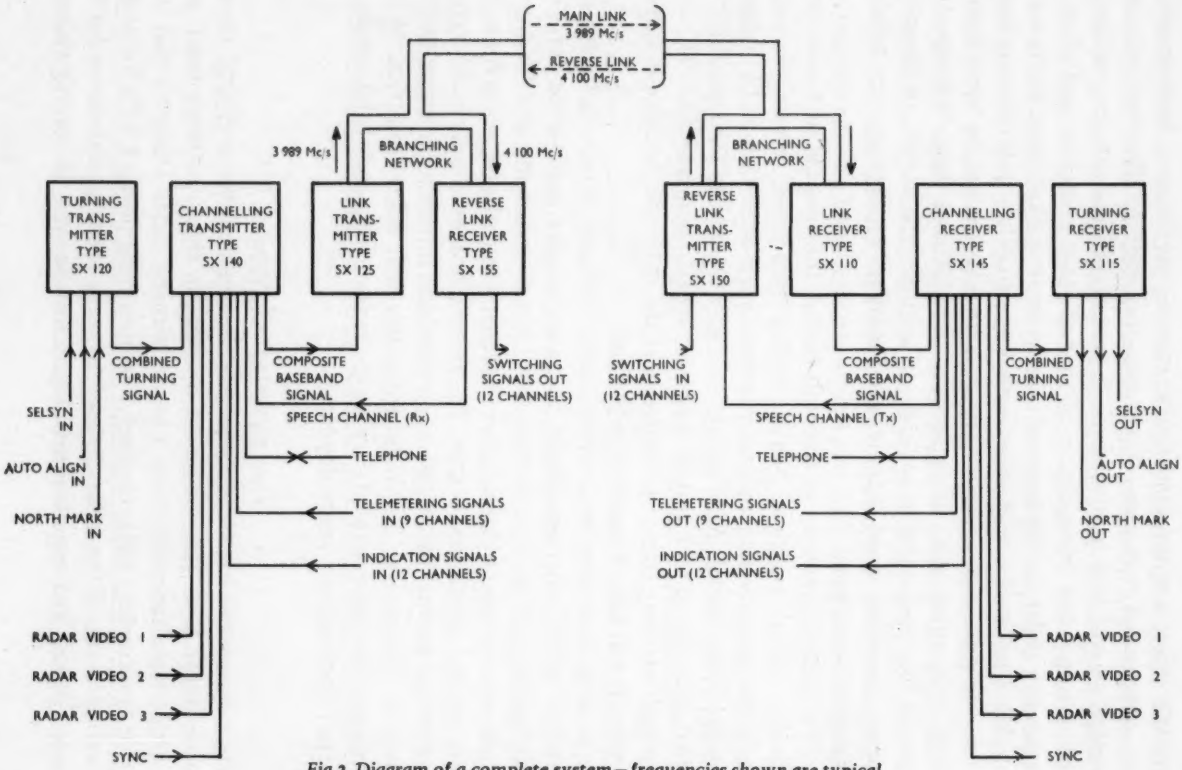

Fig.2. Diagram of a complete system—frequencies shown are typical

together with auto-align and North-marker facilities is incorporated. Nine telemeter channels for transmission of meter readings and twelve indicator lamp channels are provided in addition to an engineer's order wire speech channel.

The reverse link carries the return speech channel and 12 switching channels for performing various functions at the radar site.

The baseband of the forward link is 9 Mc/s wide and the three radar video channels are amplitude modulated on to sub-carriers at 1·0 Mc/s, 2·75 Mc/s and 4·75 Mc/s. The lower sidebands are partially removed by vestigial sideband filters.

The turning channel, which provides a mechanical shaft rotation at the receiving end of the system, operates on the principle of the phase modulation of an audio frequency signal by the aerial rotation. A magslip is driven at 30 times aerial speed via a suitable gearbox, and a 1 kc/s signal from a master oscillator is applied to the two stator windings, in phase and in quadrature respectively. The output from the rotor winding is modulated on to a 250 kc/s sub-carrier, while the original master oscillator signal, which is used as the reference, is modulated on to a 200 kc/s sub-carrier. The phase of the signal from the rotor will be shifted from that of the reference by an amount proportional to the angular position of the magslip shaft.

At the receiving terminal a similar magslip is used and the reference signal is fed in phase and quadrature to the stator windings. The signal from the rotor winding is then compared in phase with that of the signal demodulated from the 250 kc/s sub-carrier. The output from the phase comparator is fed to a servo amplifier which drives a motor which in turn rotates the magslip rotor. This shaft thus rotates in sympathy with the magslip shaft at the transmitter terminal and is therefore turning at 30 times the speed of the radar aerial. A 30/1 step-down gearbox then reproduces the original aerial shaft position and speed. Ambiguities due to the 30/1 reduction are resolved by an auto-align system which causes the interruption of a 140 kc/s signal once per aerial revolution.

The complete baseband signal is used to frequency modulate a 70 Mc/s sub-carrier, which is converted to radiated frequency in conventional fashion. This is followed by two travelling wave tube stages, the final

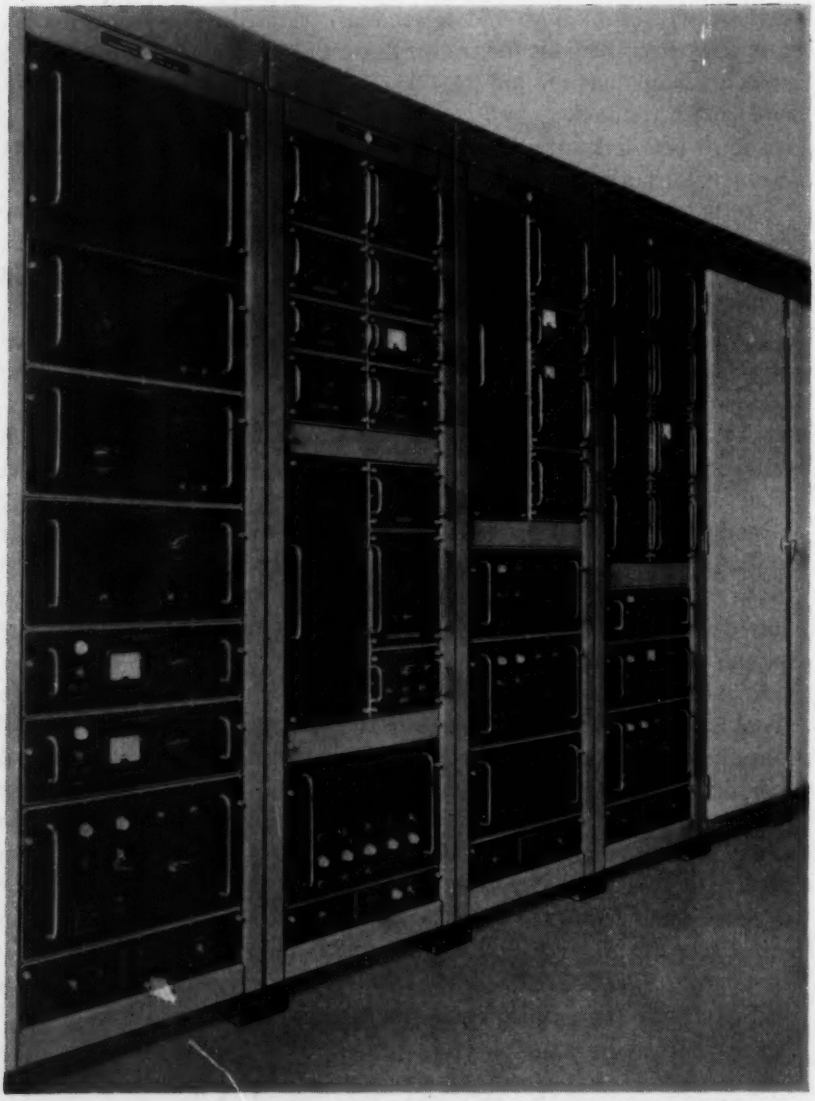

Fig.3. Typical microwave equipment for the transmission of radar information

amplifier having a power output of 4 watts. This is then fed to the aerial system which is normally a 10 foot diameter horn-fed paraboloid.

At the receiving terminal the signals from the aerial are applied to a low noise TWT followed by a crystal mixer and IF amplifier. After demodulation, the various baseband components are demodulated to recover the original signals.

Where the transmission path is obstructed, a non-demodulating repeater, employing four travelling wave tubes, may be used. The signal is first amplified by a low noise TWT, the frequency is then changed in an intermediate tube which is followed by an intermediate amplifier and a power amplifier. Such a repeater has the advantages of simplicity, great reliability and very low distortion. Up to nine such repeaters with a total path length between terminals of 300 miles may be used while still retaining a 30 dB signal to noise ratio in the video channels.

The reverse link uses a Heil tube at the transmitter terminal with a power output of 200 mW. Frequency modulation of the final carrier is again employed. Fig.2 shows a simplified block diagram of the complete system without a repeater. Typical equipment is shown in Fig.3.

A good example of the use of such a wideband link equipment is at Cook Strait, Wellington, New Zealand. Control of all civil air traffic in the Cook Strait area is carried out from the ATC building in Wellington itself. The city's airport is located at Rongotai, a suburb about five miles away, and both Wellington and Rongotai lie at sea level surrounded by steep hills. In order to obtain radar cover to a range of 100 miles or more it was necessary to locate the radar equipment at Hawkins Hill at a height of about 1 600 feet. The signals from the radar station were not only required at the ATC building in Wellington but also at the Control Tower of Rongotai Airport. The actual distances involved were not great, 4½ miles from the radar station to Wellington and 4¼ miles to the Rongotai tower. However, although the latter was just in line of sight from the radar building, the ATC headquarters in Wellington was not. As the distance involved was not very great it hardly warranted the use of a repeater and it was decided to mount a large plate reflector at Tinakori, a small hill which was in direct view from both the radar site and the ATC building. The air photograph, Fig.4, taken from a height

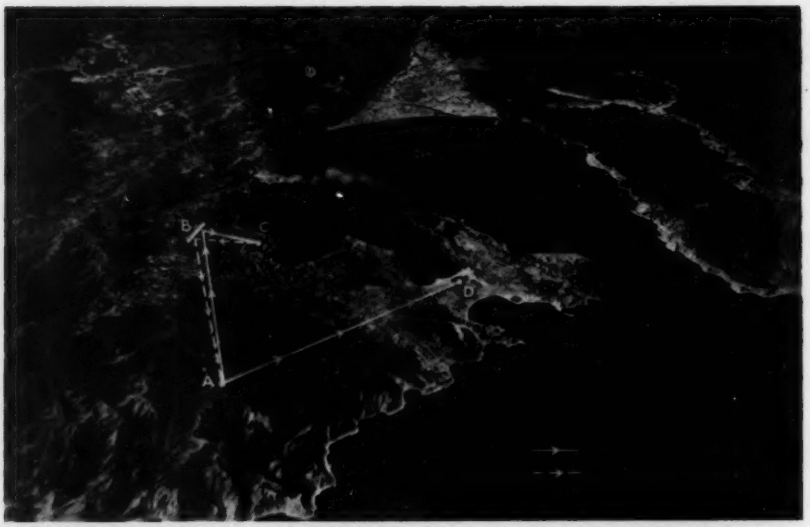

Fig.4. The Wellington Air Traffic Control area showing the microwave link paths and the disposition of display centres in relation to the radar station: (a) Radar station; (b) Reflector at Tinakori; (c) A.T.C. Centre, Wellington; (d) Rongotai Airport

Fig.5. Radar station sited at Court's Crag overlooking Rongotai Airport in New Zealand

of about 30 000 feet, shows the signal path. Only one link transmitter is employed at the radar site and its output is split between a 10 foot diameter paraboloid aerial for the Wellington path and one of 6 foot diameter for the line of sight Rongotai path. Similar sized aerials are used at the respective receiving terminals.

Very severe weather conditions are experienced during most of the year at the radar site, Fig.5. It is generally in cloud and suffers continuous and very high winds. (During installation of the equipment a wind gust of 133 knots (240 km/hr) was recorded.) Due to this and the very steep access road, the complete radar station was designed for unattended operation subject only to a daily visit by an engineer.

In addition to the transmission of two channels of radar signals (normal video and MTI video) plus aerial turning data, to Wellington and Rongotai, information about the performance of the station is sent over the link to Wellington only. The radar equipment is duplicated and the performance of both the working and standby sets and also the no-break diesel set is continuously telemetered. The reverse link connects the ATC building and the radar site via the Tinakori reflector and provides for the control of the complete installation.

The system is capable of extension to include additional channels for VHF R/T and VHF D/F as well as a wideband channel for secondary radar.

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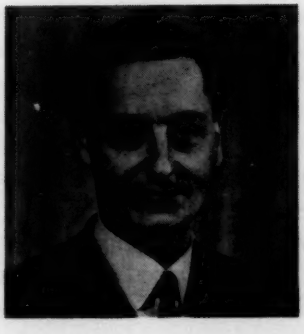
In 1946 he went to Trinity College, Cambridge, and took a degree in Natural Sciences.

He joined the Marconi Company in 1949 as a Sales Engineer attached to Radar Division (then Services Equipment Division) and joined the Systems Group of the Division on its formation in 1953. He is now the Deputy Chief of the Group with particular responsibility for Civil Aviation Systems.



The Radio Telephone Terminal

B. W. BARDWELL, B.Sc(Eng), A.M.I.E.E

The functions of the radio telephone terminal, as the means of connecting the telephone network and HF radio circuits, are discussed in this article, in the light of operational requirements, with particular reference to independent sideband working, and future trends in radio telephone practice.

1 INTRODUCTION

LONG DISTANCE HF radio telephone circuits constitute a major part of the present day international telephone network, particularly for overseas communication and where centres of population are separated by large stretches of sea and underdeveloped territory. The vagaries of HF communication caused by the limitations of the propagation medium itself call for special measures of control and supervision of such circuits, these measures being affected in the radio telephone terminal, the purposes and functioning of which are the subjects of this article.

There was virtually no technical supervision or control on early circuits using double-sideband modulation, and it was not until several years after the setting up of the first HF radio telephone circuit, in June 1928, between the United States of America and Great Britain, that radio telephone terminals came into use.

The later inauguration of single-sideband circuits, providing inherent improvement in service quality, led to more detailed consideration of the interconnecting equipment between subscribers, telephone exchanges and HF radio circuits. The present day practice of loading one independent sideband transmission with several telephone channels has

meant that technical control and supervision has to be exercised most rigidly over each channel, in order to avoid exceeding channel loading conditions, with consequent unallowable distortion.

The future will most certainly demand more and more use of cable circuits, thus eventually tending to replace HF radio circuits on major international routes. Overall HF radio-telephony usage is not likely to diminish, however, but rather to grow considerably in order to provide ancillary radio feeder circuits to the cables, or emergency back-up. The use of the radio telephone terminal, as a means of interconnecting cable and radio circuits, will therefore also expand.

The most important consideration in a telephone system is how well the message is understood by the subscriber, bearing in mind that many conversations are made in languages other than the mother tongue. The requirement is for clarity of speech, not necessarily for fidelity, and the radio telephone terminal must be designed to provide the best solution with regard to technique, economy and simplicity of operation. Its position in a typical subscriber-to-subscriber circuit containing an HF radio link is shown in Fig.1. Signals originating from the subscriber are passed via the local telephone exchange and the telephone exchange at a nearby large town, to the international telephone exchange, which makes and controls the interconnection over the radio circuit. Here the circuit is converted from a two-wire to a four-wire basis to provide separate 'go' and 'return' signals. Between the international telephone exchange and the radio equipment, both signals are processed by the radio telephone terminal; the 'go' signal then being fed to the transmitter and the 'return' signal being accepted from the receiver.

2 THE FUNCTION OF THE RADIO TELEPHONE TERMINAL

Broadly speaking, the primary functions of the radio telephone terminal are:

(1) To provide protection against circuit loop instability due to feedback

(2) To offset as much as possible the vagaries of HF radio propagation, and

(3) To normalize the levels of incoming subscribers' speech signals.

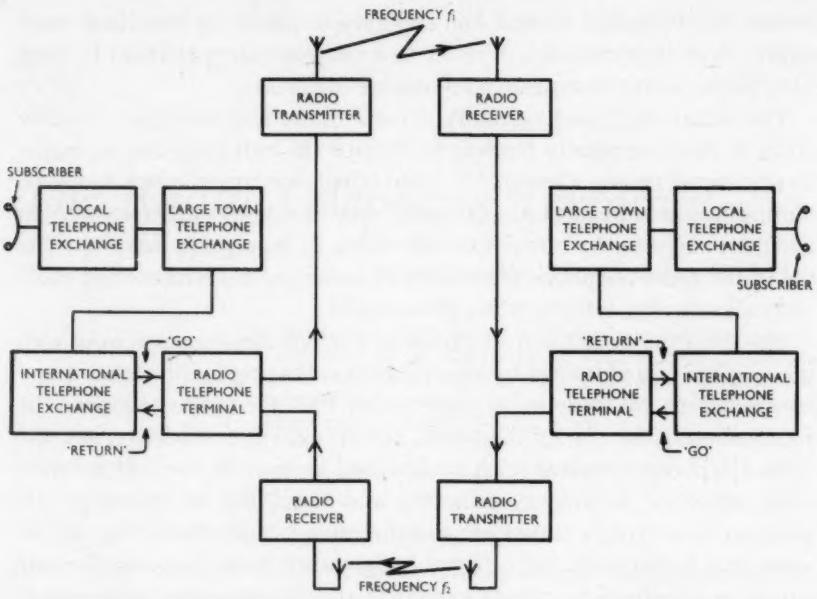


Fig.1. Block diagram showing an International HF Radio Telephone Circuit

With regard to the first function, it can be seen from the block diagram, Fig.1, that if leakage from the 'return' path to the 'go' path occurs at each of the international telephone exchanges, a feedback loop will be formed and instability may result, giving rise to 'singing' round the circuit. Theoretically, the hybrid transformers, if designed and functioning perfectly, will prevent this. However, in practice, allowing for the protection they do give, a net loop gain of up to 30 or 40 dB may occur. Additional protection is required in the form of singing suppressors, which automatically insert severe attenuation in such a manner that the 'go' path is blocked when the 'return' path is open and vice versa.

Secondly, the transmission of HF radio signals via the ionosphere gives rise to severe fading and a high level of noise. The effects of these

are greatly reduced by the use of a receive constant volume amplifier, incorporated in the return path of the radio telephone terminal. The characteristics of the amplifier are such as to provide a two-fold effect, these being:

(a) to reduce further the variation in signal level due to fading, subsequent to the automatic gain control of the receiver, thus providing a relatively constant output to line. This is very important where there are several speech channels on one transmission, as the receiver AGC functions over the whole traffic baseband and not on each channel separately;

(b) to provide zero gain at low levels to avoid amplification of noise during intervals between passages of speech, to the annoyance of the subscriber.

In the third place, to ensure maximum signal-to-noise ratio at the receiver, the transmitter must operate continuously in a fully-modulated condition. A special amplifier is required which will accept speech signals of varying level and provide a constant output for feeding to the transmitter drive. This is the transmit constant-volume amplifier.

Apart from the primary functions detailed above, several subsidiary functions, such as channel displacing and restoring, and privacy by simple inversion or band-splitting, can conveniently be incorporated. Generally speaking, simple inversion is only used these days on relatively unimportant circuits; for international circuits five-band split-privacy facilities are becoming increasingly necessary in order to provide a high degree of protection against efficient monitoring techniques.

The C.C.I.R has long recognized that it is very necessary to economize in the use of the frequency spectrum when considering long distance HF circuits, and has urged operating concerns to use multichannel independent sideband transmissions with 12 kc/s baseband (6 kc/s upper sideband and 6 kc/s lower sideband) in preference to separate double sideband transmissions. The channel displacing and restoring equipment which is required to combine two telephone channels in a 6 kc/s band is incorporated in the radio telephone terminal. Two sets will be required to accommodate four channels on the two sidebands of an independent sideband transmission.

3 DETAILED CIRCUIT ARRANGEMENTS OF THE RADIO TELEPHONE TERMINAL

Bearing in mind the foregoing reasons as to why a radio telephone terminal is required on HF circuits, the block diagram detailed in Fig.2 follows a logical pattern.

Assuming that the interconnection between the exchange and the radio telephone terminal is on a four-wire basis, speech entering the radio telephone terminal from line is first of all processed by the transmit constant volume amplifier. The signal then passes to the transmitter

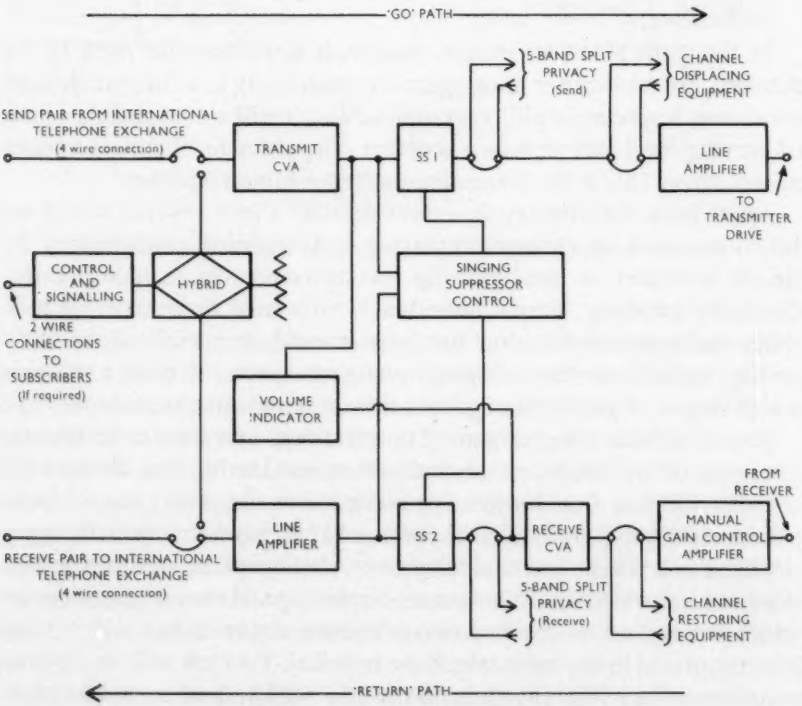


Fig. 2. Block diagram of Radio Telephone Terminal

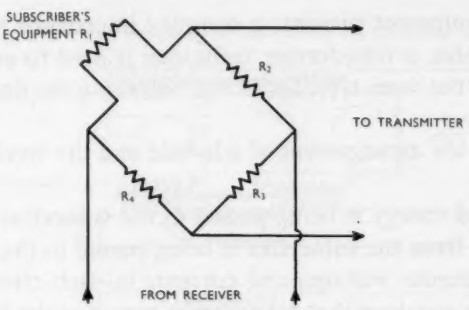


Fig.3. Fundamental hybrid network

drive via the 'go' singing suppressor circuit (SS1) and a manually controlled line amplifier.

'Return' signals originating from the receiver enter the receive half of the radio telephone terminal via a manual gain-control amplifier and are subsequently fed to the receive constant volume amplifier. The signal is then passed through to the receive singing suppressor (SS2) before being fed over line to the international telephone exchange via a manually controlled output line amplifier.

At points just before and just after the singing suppressors in the 'go' and 'return' paths, signals are taken off which, when rectified, actuate the singing suppressor control circuits.

Other points to notice in Fig.2 are the position of the removable links for inserting privacy and channel displacing and restoring equipment and the hybrid network with the control and signalling panel which allows the terminal to be used in the role of a simple telephone exchange.

3.1 THE HYBRID NETWORK

The simplest form of hybrid network is a resistance bridge, shown in Fig.3, with the usual balance condition ensuring that no energy arriving from the receiver is transferred to the transmitter (i.e no feedback (singing) will occur round the circuit). This type of circuit is unsatisfactory, however, as energy is lost in the resistors, and because the

subscriber's equipment presents a complex impedance to the network. To overcome this, a transformer technique is used to provide a bridge circuit, this at the same time facilitates balancing the lines with respect to earth.

Fig.4 shows the arrangement of a hybrid and the working conditions when

(a) the received energy is being passed to the subscriber, and

(b) the energy from the subscriber is being passed to the transmitter.

The instantaneous voltages and currents in each circuit are then as shown and it is apparent that cancellation occurs in the inactive branch. The degree of equality of impedance presented at the hybrid by the subscriber's line and the balancing load determines how much energy is transferred to the transmitter circuit when energy is coming from the receiver.

In theory it is possible to obtain a perfect balance, but due to the complex impedances encountered in practice, only a moderately good balance can be obtained over the working frequency range. The situation is made much worse when many different subscribers of an inland telephone system with their varying lengths of line have to be passed through the one hybrid network.

3.2 SINGING SUPPRESSORS

The mechanical relays originally used to make and break the circuits have now been replaced by networks of non-linear elements, termed static relays, which insert attenuation of the order of 110 dB into the appropriate path by means of DC control current reversals.

At each end of a radio link four conditions are possible when no speech is present. These are:

(1) 'Go' and 'Return' paths — both open.

(2) 'Go' path open; 'Return' path blocked.

(3) 'Go' path blocked; 'Return' path open.

(4) 'Go' and 'Return' paths — both blocked.

By inspection of various combinations of end conditions it is soon apparent that the condition (3) for both ends is the one most suited for

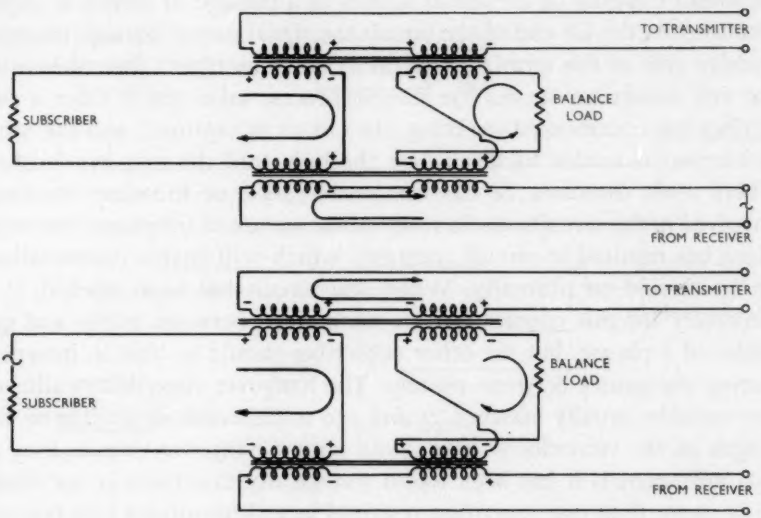


Fig.4. Hybrid network: (a) Signal from receiver to subscriber; (b) Signal from subscriber to transmitter

radio telephone link working, and is in fact the one used in present day fixed circuits, and is sometimes termed VODAS (voice operated device, anti-singing).

It is interesting to note here that the 4 : 4 combination has been used, and is the basis of the American CODAN (carrier operated device, anti-noise). This system is particularly suitable for ground to air R/T aeronautical circuits.

A simplified singing suppressor circuit is shown in Fig.5 and shows the circuit in the rest condition (i.e with the receiver connected through to the subscriber's line via the hybrid).

When the subscriber speaks, a signal passes through the hybrid into the 'go' path. This signal is detected by the suppressor control which opens the circuit to the transmitter and blocks the circuit from the receiver. This operation is completed in a few milliseconds, and the

resultant clipping of the initial sounds of a passage of speech is imperceptible. At the far end of the circuit the signal passes through the open receive side of the terminal and on to the subscriber's line. When the far end subscriber speaks the reverse process takes place. Once a subscriber has commenced speaking, the circuit is captured, and the other subscriber is unable to speak over the link until the first has finished. There must therefore be careful consideration of the time constants involved in the circuits, and a study of the nature of telephone conversations has resulted in circuit constants which will enable conversations to be carried on normally. When one circuit has been opened, it is necessary for this condition to be maintained between words and syllables of a phrase, but the other subscriber should be able to interrupt during the pauses between phrases. The hangover time delays allowed are variable, usually between 75 and 250 milliseconds depending on the length of the subscribers' lines. Even with a hangover time as long as 250 milliseconds it has been found statistically that there is not likely to be more than one repetition required in a three-minute call because both subscribers are speaking at once. It has been noticed that subscribers used to long distance radio telephone conversations adopt habits which suit the medium, and await a definite pause before replying.

The circuit as discussed in Fig.5 does not protect against speech and noise coming in from the receiver passing into the 'go' path of the terminal at such a level as to operate the suppressor circuit, thus opening the 'go' path and blocking the 'return' path. Instability of this sort is prevented by a lock circuit (see Fig.6, which shows the circuit in the rest condition), which ensures that the 'go' path remains blocked when speech is coming in from the receiver. Discrimination between speech and noise is necessary and a further circuit is required to protect the system against instability from noise only. This device is known as the differential balance and its position in the circuit is shown in Fig.7 (circuit in the rest condition).

The differential balance measures the signal levels in the 'go' and 'return' paths and so long as these levels remain substantially constant, as with noise, it prevents any operation of the suppressor control. If the level of signal in the 'go' path increases significantly with no change of

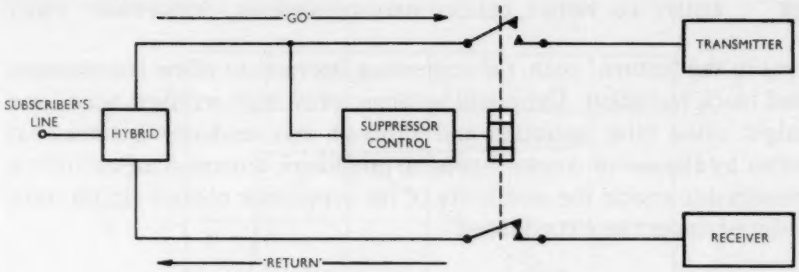


Fig.5. Singing suppressor—basic circuit

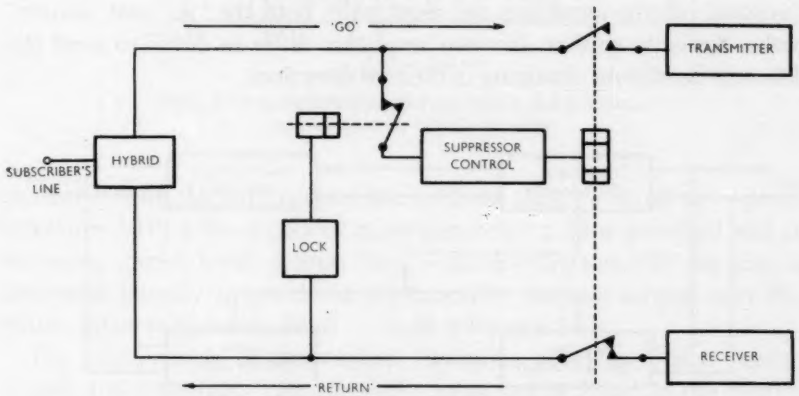


Fig.6. Singing compressor—showing addition of lock circuit

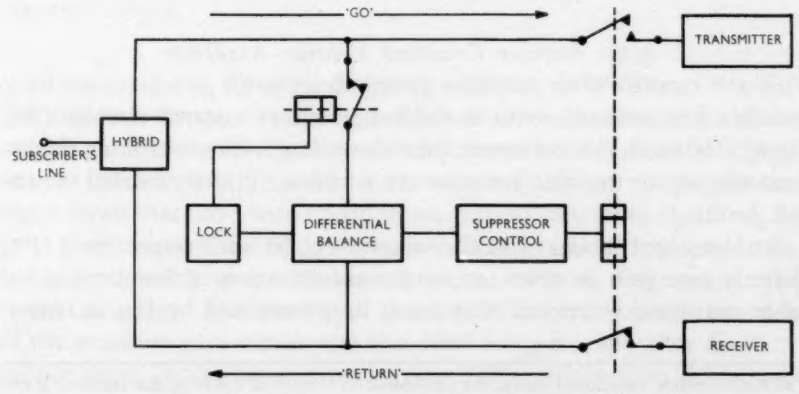


Fig.7. Singing compressor—with lock and differential balance

that in the 'return' path, the suppressor operates to allow transmission and block reception. There will be times when high received noise level might cause false operation and although this tendency is somewhat offset by the use of constant volume amplifiers, a manual adjustment is provided to enable the sensitivity of the suppressor control circuit to be reduced under these conditions.

3.3 CONSTANT VOLUME AMPLIFIERS

Constant volume amplifiers are required in both the 'go' and 'return' paths. Basically similar, the two amplifiers differ in detail to meet the different conditions obtaining in the two directions.

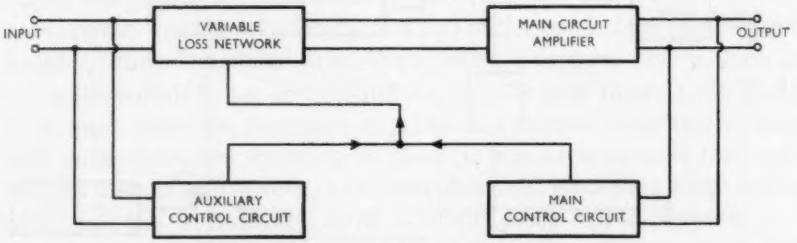


Fig.8. Receive constant volume amplifier

3.3.1 *Receive Constant Volume Amplifier*

This unit consists of an amplifier giving about 40 dB gain preceded by a variable loss network with main and auxiliary control circuits (See Fig.8). The main control circuit provides voltages for controlling the attenuation of the variable loss network which are directly related to output level.

At low input levels, typically below −35 dB with respect to RTP*, there is zero gain in order to prevent amplification of low level noise when no signal is present. Control is here exercised by the auxiliary

* RTP—Reference Telephonic Power—is equivalent to a level of 6mW in 600 ohms at a frequency of 1000c/s.

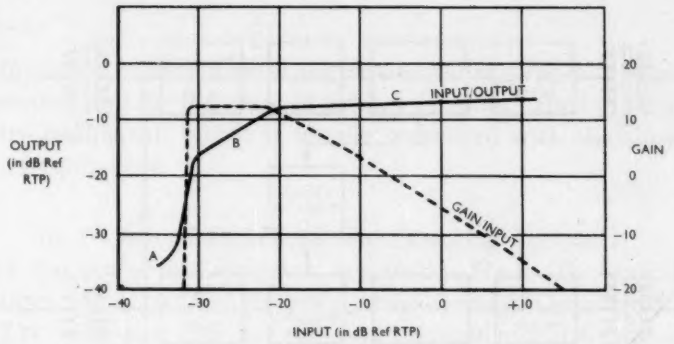


Fig.9. Typical input/output and input/gain characteristics —receive constant volume amplifier

control circuit. At intermediate levels (from about −30 dB to −20 dB reference RTP) a fixed gain of approximately 12 dB is provided and at incoming speech levels greater than −20 dB reference RTP the gain is decreased linearly to provide a substantially constant output over the whole input range −20 dB to +10 dB reference RTP.

The combination of the various functions provides typical input/output and input/gain characteristics as shown in Fig.9. In the former 'A' is the region of zero gain, 'B' that of fixed gain and 'C' that of constant output.

3.3.2 *Transmit Constant Volume Amplifier*

The transmit constant volume amplifier circuit is similar to that of the receive amplifier but with one or two refinements. With a similar input/output characteristic, it provides the required constant output for line input levels that have been found in practice to vary from about −5 dB to −40 dB relative to RTP. It responds rapidly to sudden increases in the level of incoming speech, but much more slowly to decreases. In the former case there is a time lag of about 2 milliseconds before reduction of the amplifier gain occurs, the final level being reached after about 20 milliseconds. In the latter case the time factor depends on subsequent speech.

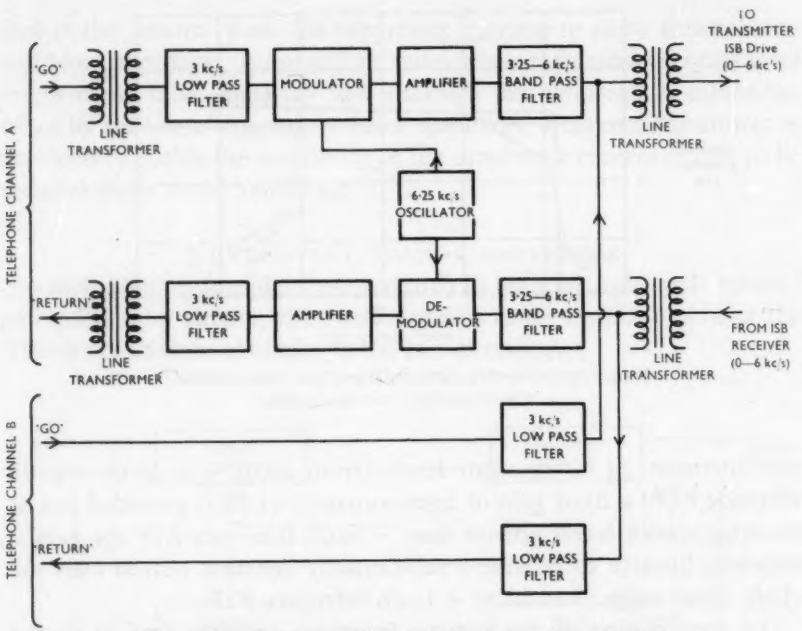


Fig.10. Diagram of channel displacing and restoring equipment

If the incoming speech ceases for either short or long periods, the gain of the amplifier remains virtually unchanged, thus allowing for pauses in the conversation. On the resumption of speech either one of two things can happen. If the speech level is greater than the preceding speech level then the amplifier gain is rapidly reduced. If the speech level is less, then the gain of the amplifier is increased in steps of the order of 3 dB at every syllable, the stepping being actuated by a syllabic detector.

The protection afforded by the transmit constant volume amplifier against low level noise is the same as for the receive amplifier. However, the former, incorporating a syllabic detector, differentiates between the steady character of noise and the syllabic nature of speech and prevents the amplification of high level noise in the absence of speech.

3.4 ANCILLARY EQUIPMENT

The practice of loading several telephone channels on to a single ISB transmission, and the provision of privacy facilities calls for additional ancillary equipment, which is usually associated with the telephone terminal equipment.

3.4.1 *Channel Displacing and Restoring Equipment*

A block diagram of this equipment is shown in Fig.10. The audio input on channel 'A' (250 c/s – 3 000 c/s) passes through a line transformer and a 3 kc/s low-pass filter to a ring type balanced modulator fed with a 6·25 kc/s carrier from a crystal oscillator. The output is then passed, via a line amplifier, to a 3·25 – 6·0 kc/s bandpass filter. Thus the original signal has been displaced and inverted. The audio input to channel 'B' passes through a low-pass 3·0 kc/s filter and is combined with the displaced signal from channel 'A'. The 250 c/s to 6 000 c/s signal is then fed to either sideband input of the independent sideband transmitter drive. Reverse processes accomplish channel restoration on the return path.

3.4.2 *Five-Band Split-Privacy*

Five-band split-privacy equipment divides a 250 c/s to 3 000 c/s speech channel into five equal sub-bands of 550 c/s. The equipment then rearranges these sub-bands into preset combinations to form a scrambled speech channel of the same band width in the same position in the frequency spectrum. At the other end of the link, the receive half of the equipment reconverts the scrambled speech into a normal speech channel by a reciprocal process. In addition to the rearrangement of the sub-bands, each can be inverted to provide additional protection. Thus the total number of combinations available is 3 840 (i.e, $5! \times 2^5$). However, not all of these provide a high degree of privacy, and certain combinations are not used. Privacy equipment is so designed that it can be pre-set for certain of the combinations, the particular one in use at any one time being selected manually by the operator. Additional security is available by automatic sub-band switching where six pre-set combinations are selected automatically by switching them in a thirty-six term

sequence. The sequence is repeated after every run during which time each of the combinations is retained for between four and twenty seconds. Either high stability oscillators (of the order of 1 in 10^7) or pulsed synchronizing facilities have to be provided, so that the equipments at each end of the link keep in switching step.

The band splitting and transposing arrangements for either the 'go' or 'return' path of one telephone channel are shown in Fig.11. The input audio signal is split into five (reference A, B, C, D and E) and each is modulated with a carrier frequency selected from 4 050 c/s, 4 600 c/s, 5 150 c/s, 5 700 c/s, or 6 250 c/s. From each of the five different frequency bands so formed, the band 3 250 – 3 800 c/s is selected by bandpass filters, with the result that different parts of the original intelligence are now present on the separate paths. Each signal is then passed through another modulator into which 7 050 c/s can be fed, to effect inversion. Further modulation has to take place in order to transpose the signals into adjacent bandwidths before combining into the final output signal; the modulating frequencies mentioned above now being used in fixed order. Fig.12 shows the above sequence of events, with the speech channel being assumed divided into five intelligence bands, 1, 2, 3, 4 and 5.

For example it has been arranged that:

(a) Path 'A' is modulated by the 4 600 c/s oscillator
Path 'B' by 6 250 c/s
Path 'C' by 4 050 c/s
Path 'D' by 5 150 c/s
Path 'E' by 5 700 c/s
to give the arrangement shown at Stage 3, and

(b) that sub-bands A, B and D are inverted at Stage 5.

Band splitting obviously provides far superior privacy to that obtained with simple inversion. For satisfactory operation, however, much less radio distortion can be tolerated especially that due to selective fading. This applies even more with the automatic synchronous system where it can be very difficult to maintain the switching sequences in step.

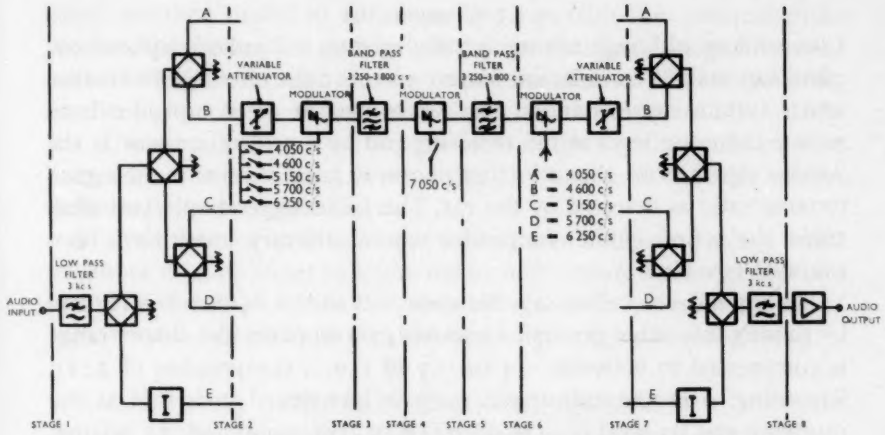


Fig.11. Simplified block schematic 5-band split-privacy equipment

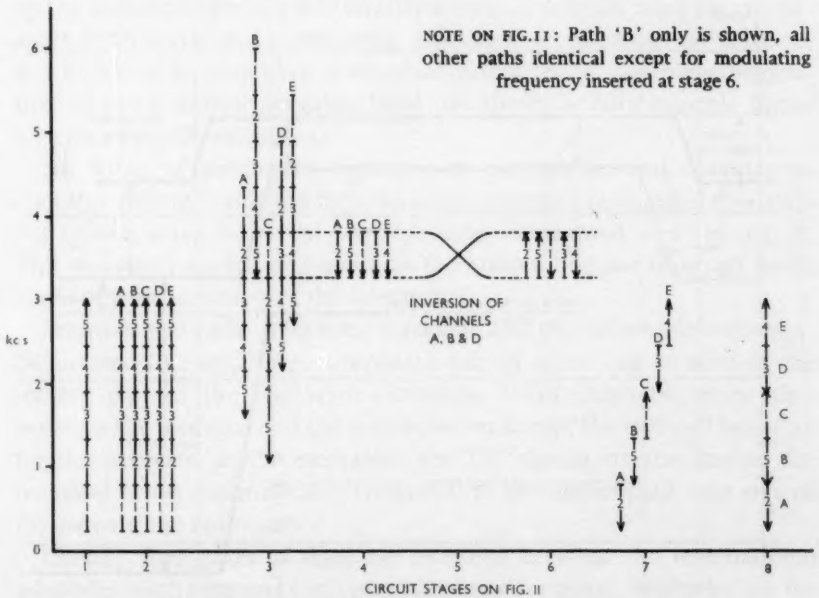

NOTE ON FIG.11: Path 'B' only is shown, all other paths identical except for modulating frequency inserted at stage 6.
INVERSION OF CHANNELS A, B & D
kc/s
CIRCUIT STAGES ON FIG. II

Fig.12. Typical transposition sequence – 5-band split privacy equipment

3.4.3 *Compandors*

Compandors, although not universally used on HF radio telephone circuits, can make a considerable improvement in the circuit performance under certain circumstances. The whole idea of the compandor is to reduce the noise level at the receiving end by a greater amount at the weaker signal levels, thus effecting an overall improvement in the signal-to-noise ratio as detected by the ear. The following example best illustrates the action of the compandor where arbitrary levels have been assumed (see Fig.13).

The input level varies, say, between −8 and −14 dB ref. RTP, and by passing this signal through a variable gain amplifier the output range is compressed to between −4 to −7 dB (i.e, a compression of 2 : 1). Supposing, over the radio path, noise is introduced such that at the receiving end its level is −16 dB ref. RTP. This noise and the original

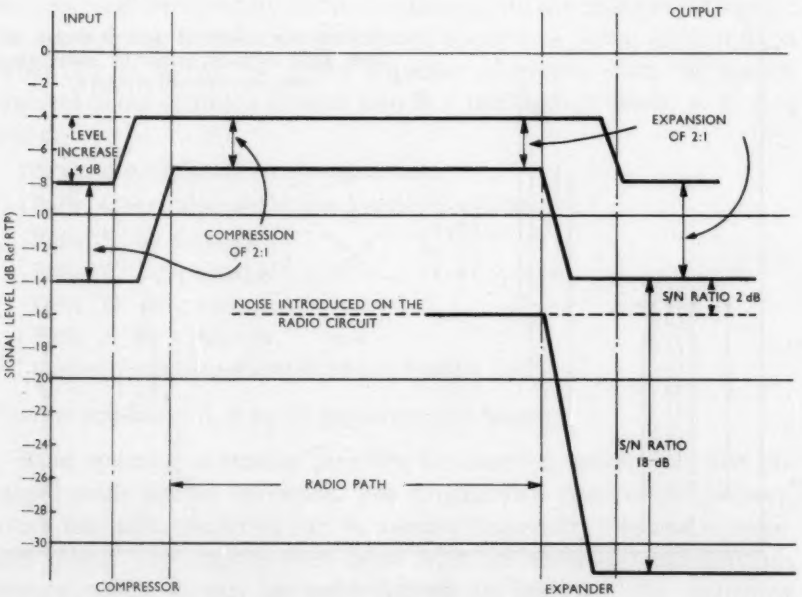


Fig.13. The principle of operation of the compandor

signal are then passed to the expander (a variable loss attenuator) to provide, for the weaker passages of the speech signal, a signal-to-noise ratio of 18 dB (compared to only 2 dB in the absence of a compandor). For the highest levels of the speech signal the improvement is relatively less. The overall result is an improvement in the signal-to-noise ratio as judged by the ear, bearing in mind that this improvement only applies to intervals between syllables.

It is felt that the quality of many international high frequency radio telephone circuits might be improved by more extensive use of the compandor, and the C.C.I.R, in fact, does allow a 10 dB factor for the use of noise-reducing devices when calculating circuit signal-to-noise ratios.

4 OPERATIONAL CONSIDERATIONS

Because of the nature of HF radio telephone circuits, operation and control has to be effected on a manual basis. Once the call has been set up the technical operator will usually dissociate himself from the circuit, apart from occasional monitoring, unless radio conditions are adverse, in which case he may have to monitor continuously. Complete dissociation of the technical operator from the circuit is only possible under high merit circuit conditions.

No form of automatic signalling is permissible and operator-to-operator calling is effected by a manually operated modulated tone calling system using a 500 or 1 000 c/s tone interrupted at 17 or 20 c/s. This signalling source originates on the radio telephone terminal itself, and is under the control of the operator.

Between the radio telephone terminal and the telephone exchange, DC is used for signalling. A separate pair of wires can be used or the receive pair of the four-wire extension. With four-wire connection between the terminal and the telephone exchange, the call will be set up by the operator at the exchange, the DC signals on the line to the terminal being automatically converted to the interrupted tone signals for use over the radio path.

Usually four pairs of lines are provided between the international telephone exchange and the radio telephone terminal, two pairs are for the 'go' and 'return' traffic signals, one pair is an engineers' order wire

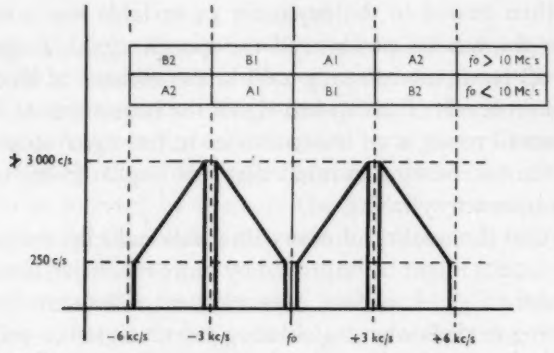


Fig.14. Arrangement of four telephone channels ISB transmission

linking the exchange operator and the technical operator at the radio terminal, and the other pair is for feeding monitoring signals from the telephone terminal to the operator at the international exchange. Two extra pairs may be provided for engineer order wire circuits linking the radio telephone terminal to the transmitting and receiving stations.

In cases of emergency or breakdown of the circuit the technical operator at the radio telephone terminal can, by means of a master control key, take over the operation of the radio circuit completely.

The practice of loading independent sideband transmissions with multichannel telephony is increasingly widespread, and considerable care has to be exercised to avoid cross-talk. Transmitters have reached the economic limit of linearity (IPs of −36 dB with reference to PEP), and consideration has therefore to be given to the channel arrangement in the traffic baseband. C.C.I.R Recommendation No. 249 (Los Angeles 1959) gives the channel arrangement shown in Fig.14, which reduces cross-talk annoyance to the subscriber to a minimum.

It is generally reckoned that cross talk on adjacent channels in the same sideband is of the order of 6 dB higher than adjacent channels on either side of the carrier and that between outside channels is non-existent. For this reason it is preferable that a second telephone channel added to an existing single channel independent sideband transmission

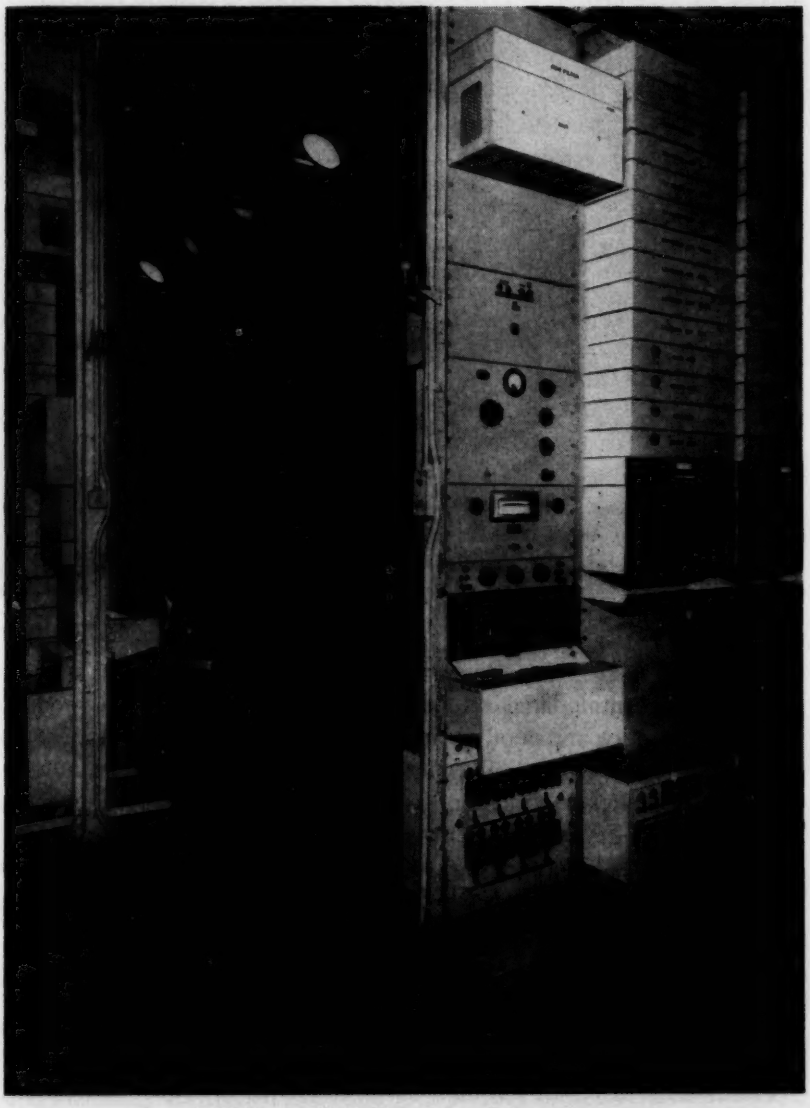


Fig.15. G.P.O Brent Radio Telephone Terminal – equipment room

Fig.16. G.P.O Brent Radio Telephone Terminal—supervisor and engineer control positions

should be accommodated on the other sideband. Assuming modern operating practice and good equipment design, cross-talk in fact causes very little trouble. It has been estimated from operational data that with normal four telephone channel loading conditions (i.e, each channel level at −10 dB reference RTP) the transmission is distorted for several millisecond periods occurring at a rate of ten to thirty per minute. This distortion is considered to be about 1% only of the duration of the speech passage.

The equipment layout at radio telephone terminal centres depends entirely on local conditions of traffic density and space available. Although no two centres are alike they can be considered very broadly in three groups.

Firstly there are those terminal centres attached to major world cities, the G.P.O terminal at Brent, London, is typical. Here the vast amount of

equipment utilized demands a building specially designed for its accommodation. The equipment is necessarily dispersed into equipment rooms (see Fig.15) and operator control is effected from remote control consoles in another part of the building (Fig.16).

The majority of radio telephone terminal centres in the world fall into the second group where something of the order of 5 to 20 circuits are catered for. This type of centre calls for extreme flexibility and reliability, as spare equipment capacity is normally not available. A good example is the Cable and Wireless Limited Station at Hong Kong (see Fig.17) which comprises five suites, each of which is controlled by a technical operator who in this case, as distinct from the Brent Terminal, exercises direct supervision. Up to fourteen speech channels are accommodated, four of which can be combined into two pairs for independent sideband operation. Inverter privacy is available for all channels simultaneously and five-band split-privacy on any two. Additional equipment comprises a four-wire relay and standard speech tape recorder for test purposes.

Thirdly there are very simple types of network where any one of four or five subscribers can be connected to a radio circuit. Here the radio telephone terminal acts as a small telephone exchange as well as providing the connections to the radio circuit. In this case the operator sets up all the calls and provides the technical supervision.

5 EQUIPMENT DESIGN

The radio telephone terminal operating at audio frequencies and relatively low orders of power is an ideal application for transistors and printed circuit techniques. Although the basic functions have changed very little over the last twenty years, these modern techniques enable considerable reduction to be made in the overall size and in the power consumption of the equipment. Fig.18 is a photograph of a typical modern radio telephone terminal and an estimate of size reduction can be gained when it is realized that this terminal has a capacity for two telephone channels and is complete with channel displacer and restorer and manually controlled five-band split-privacy on each channel.

The reduced size of the terminal asks for greater care in mechanical

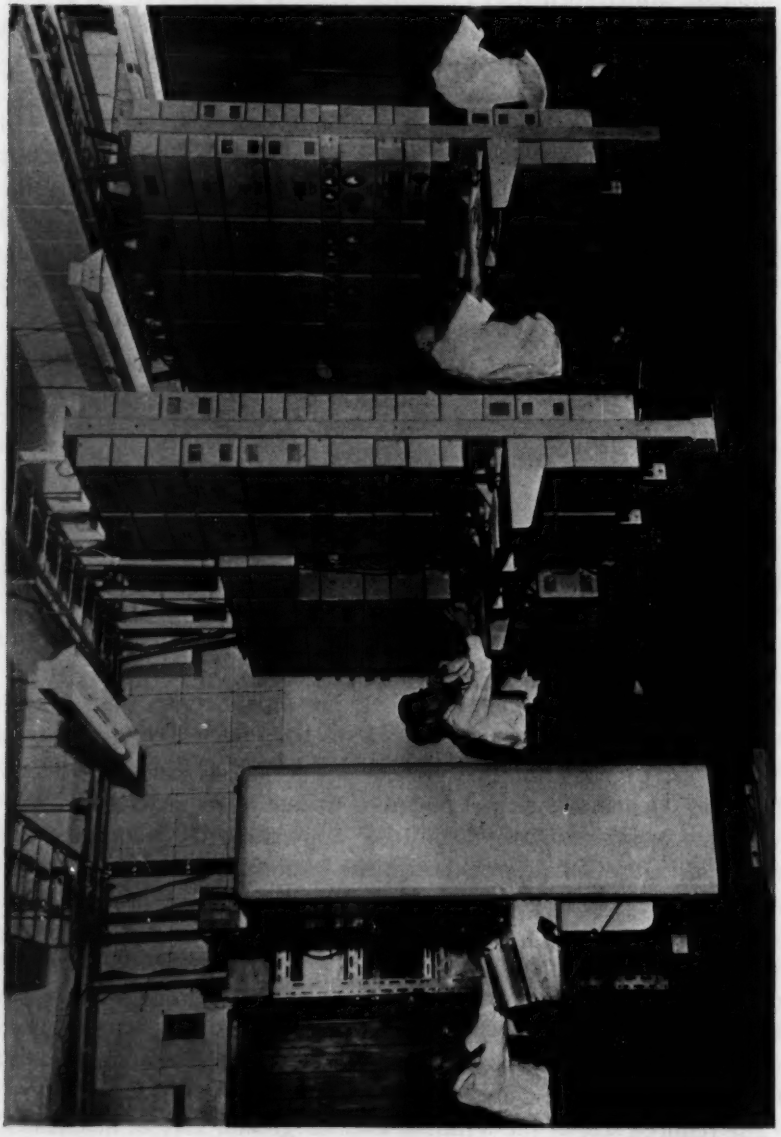


Fig.17. Cable and Wireless Ltd Radio Telephone Terminal Centre, Hong Kong

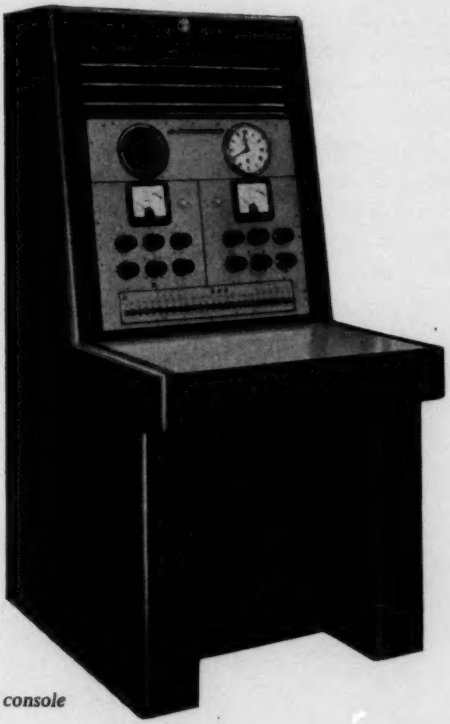


Fig.18. Radio Telephone Terminal console

design, and ease of maintenance and accessibility assume major importance. However, the use of transistors and components mounted on plug-in printed circuit cards has made possible a modular form of construction as shown in Fig.19. In many instances, cards are grouped to provide integrated units for a particular function.

6 FUTURE DEVELOPMENTS

HF radio telephone systems have to meet two conflicting requirements. Firstly, the user tends to demand ever-improving fidelity, particularly in view of the high standards attained by cable and line-of-sight microwave radio circuits, and secondly, the telecommunications engineer is

endeavouring to use the intelligence bandwidth over the radio path more efficiently, whilst at the same time maintaining adequate intelligibility.

Both requirements have cost as a limiting factor. This, together with the technical difficulties presented by the overcrowding of the HF band, which will be accentuated during the forthcoming sunspot minimum period, may lead to the viewpoint of the engineer taking precedence.

It may well transpire that in the future two grades of circuit will be available, one based on sufficient intelligibility at a cheap rate for commercial use, and the other based on less efficient use of the baseband but providing higher fidelity at increased charge; the latter probably being available in off-peak loading periods when convenient.

There is no doubt that equipment which increases the intelligence capacity of an existing link, even though it may reduce fidelity and be costly, forms a very desirable system addition, particularly when the

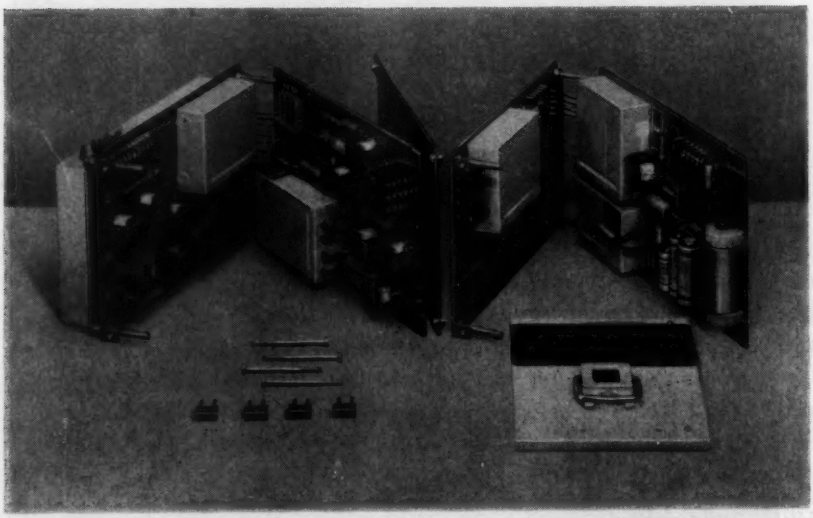


Fig.19. Modular unit form of construction as used in a modern Radio Telephone Terminal design

costs of installing and operating duplicate circuits and the difficulty of obtaining frequencies in an already overcrowded band are taken into account.

Speech is of a sporadic nature and a way of automatically interleaving conversations on a time sharing basis by means of a syllabic detection principle has been developed. This is the essential feature of the TASI System (Time Assignment-Speech Interpolation) which is at present in use on cable circuits, as a result of which the channel capacity has been almost doubled.[1] From practical work carried out it appears that doubling the number of telephone channels will only increase the channel loading factor by the order of 1 dB.

Although the TASI system has so far only been used on cable circuits, in the author's opinion, the principle may well be applied to certain HF circuits of high-merit without noticeably affecting performance. The channel capacity could probably be increased by 25% without incurring a disproportionate number of 'freeze-outs' (these occur when the number of available channels is less than the number of subscribers wishing to speak). Furthermore, the percentage increase might well be larger if the system was applied to parallel transmissions where the initial channel capacity is greater.

A large amount of work has also been carried out on ways of compressing the bandwidth of individual speech channels below that normally considered the minimum for satisfactory reproduction. As development proceeds, it may well be that in the future, a number of speech channels will be contained within the band which is now normally required by one. As far back as 1936 Homer Dudley's ingenious speech analysing and synthesizing machine, the Vocoder[2] (voice coder) had achieved the transmission of intelligible speech by means of eleven channels, each 25 c/s wide (i.e, a total bandwidth of 275 c/s). Compared with present day systems this means a compression ratio of 10 : 1.

Of the two methods it would appear that the second gives the maximum advantage, and present work being carried out may well result in a considerable increase in telephone channel capacity on existing HF radio links. The Vocoder has probably reached the limits of tolerable bandwidth compression and the TASI system the limits of compression

by means of time division multiplex. The two systems may well, however, be operated complementarily but in any case either system may be forced into operation by the overcrowding of the HF band.

Acknowledgement

The radio telephone terminal illustrated in Figs. 18 and 19 has been designed by Automatic Telephone & Electric Co Ltd, under the direction of Mr T. B. D. Terroni, Manager of the Transmission Division. The author would particularly like to acknowledge the assistance given by the engineer in charge of the project, Mr P. Tyler, in the preparation of parts of this article.

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SEITE 3

STANDPUNKTE

Die zwischen zwei beliebigen Fernsprechteilnehmern zur Verfügung stehende Übertragungsgüte wird hauptsächlich von wirtschaftlichen Faktoren diktiert. Die Teilnehmereinrichtungen und die Ortsnetze, welche den grössten Teil der Kapitalanlagen bilden, bestimmen gemeinsam die Übertragungsgüte. Die C.C.I.F empfiehlt, dass die Gesamtdämpfung auf einen Betrag von 40dB beschränkt bleiben soll, von dem 18dB auf die Sendeseite entfallen können. Die Qualität der Verbindung blieb grundsätzlich unerwähnt. Weil das Fernverkehrsnetz nur einen kleinen Teil der Gesamtanlage ausmacht, muss dessen Übertragungsgüte so hoch sein, dass die Gesamtübertragung von Teilnehmer zu Teilnehmer dadurch nicht merkbar verschlechtert wird. Bei der Übertragung von kleinen Kanalzahlen über verhältnismässig kurze Entfernungen war dies niemals ein grosses Problem. Als jedoch Vielkanal-Funkverbindungen eingeführt wurden, bestand die Tendenz, die Normen für die Übertragungsgüte auf Drahtverbindungen direkt auf Funkverbindungen zu übertragen, ohne die auf dem Funkwege vorhandenen Einschränkungen voll zu berücksichtigen.

Bei der Ausdehnung der internationalen Netze wurden die empfohlenen Gütewerte für Fernverbindungen noch weiter erhöht. Diese haben jetzt einen solch hohen Wert erreicht, dass es zweifelhaft erscheint, ob die Hauptverbindungswege in Europa diesen Wert erreichen. Trotz der hohen Entwicklungskoten stehen auf dem Gebiete des Funkverkehrs erst jetzt Geräte zur Verfügung, welche die C.C.I.R-Empfehlungen voll erfüllen und es ist zweifelhaft, ob genügend Spielraum vorhanden ist, um diese Güte wirtschaftlich beibehalten zu können.

Troposphärische Streustrahlverbindungen mit voller C.C.I.R-Übertragungsgüte sind wirtschaftlich nicht durchführbar. Selbst bei Unterwasser-Fernsprechkabeln wird aus wirtschaftlichen Gründen ein geringerer Kanalabstand und eine Mehrfachausnutzung der Kanäle angewendet. Wenn Verbindungswege mit Satelliten eingeführt werden, dann ist es sehr fraglich, ob diese die C.C.I.R-Empfehlungen erfüllen.

Verbesserungen der Fernsprechapparate und der Ortsnetze ergeben eine viel bessere Sprachübertragung und die Dämpfung für den grössten Teil der Teilnehmer liegt erheblich unter dem erlaubten Maximum von 18dB. Eine Reduzierung der Normen für Fernverbindungen um 6dB würde die C.C.I.R-Empfehlungen der nordamerikanischen Fernverkehrspraxis angleichen, welche dem Bell-Fernsprechnetz einen sehr guten Standard verleiht. Dadurch würden sich die Probleme der Konstruktion und insbesondere der Wartung erheblich vereinfachen.

Geräte für einen grossen Teil des zukünftigen Fernverkehrsnetzes befinden sich jetzt im Entwicklungsstadium, gleichgültig ob es sich dabei um verstärkte Koaxialverbindungen oder eine der vielen Lösungen für den Funkbetrieb handelt. Eine Neuabschätzung der vor der weitverbreiteten Einführung dieser Mittel festgelegten System-Normen wäre nicht unangebracht und sollte im Licht der heutigen Anforderungen erfolgen.

SEITE 6

EINE BEMERKUNG ZUM WEITVERKEHR ÜBER SATELLITEN

von M. Telford

Die praktische Monopolstellung der Kurzwellenverbindungen im internationalen Fernsprech-Weitverkehr wird von den transatlantischen Breitbandkabeln ernsthaft strittig gemacht. Obwohl diese ausserordentlich teuer sind, deutet die sich mit ihnen erzielbare hohe Verkehrskapazität und Übertragungsgüte darauf hin, dass der Hauptteil des Fernsprech-Fernverkehrs zwischen den Hauptlandmassen sich in den nächsten 10 bis 20 Jahren auf Koaxialkabel verlagert. Die einzige zur Zeit übersehbare Alternativlösung ist die Benutzung von Erdsatelliten. Die neuerliche intensive Untersuchung dieser Methode hat gezeigt, dass sowohl passive als auch aktive Satelliten-Verstärker möglich sind. Erstere wurden mittels des Ballonreflektors 'ECHO' experimentell untersucht. Selbst mit Sendern von 10kW Ausgangsleistung und bei Benutzung von grossen Antennen an beiden Endstellen ist die Kapazität dieser experminentellen Anlage jedoch nur auf einen Sprachkanal beschränkt. Obwohl sich dies zweifellos noch erheblich verbessern lassen wird, sind die Aussichten auf eine wirtschaftliche Erreichung einer grossen Verkehrskapazität nicht sehr gross. Für ein Rausch-

verhältnis von 40 dB in einem Basisband von 5 MHz Breite muss an jeder Endstelle ein 100 kW Sender mit Antennen von 50 m Durchmesser benutzt werden. Bei aktiven Satelliten kann ein ähnliches Ergebnis mit einer Strahlungsleistung von 1 W und einer Antenne von 20 m am Empfänger erreicht werden. Bei Berücksichtigung der geringeren zu erwartenden Empfängerleistung in dem Satelliten erscheint eine Senderleistung von 1 kW in der Bodenstation angebracht. Es lässt sich mit Sicherheit behaupten, dass die für eine erfolgversprechende Anlage mit aktiven Satellitenverstärkern notwendigen Funkgeräte im Bereich der jetzigen technischen Möglichkeiten liegen, obwohl viele Probleme von Konstruktionseinzelheiten, besonders im Hinblick auf die Zuverlässigkeit der Schaltungsteile, noch eine Lösung erfordern.

Die Reservierung des notwendigen Frequenzspektrums wird von grosser Wichtigkeit sein. Die oben angegebenen Schätzungen basieren auf einem FM-System mit grossem Frequenzhub, welches bei einem passiven Satellitenverstärker eine Bandbreite von 250 MHz benötigt oder bei einem aktiven Satellitenverstärker 500 MHz benötigt, wenn auf einer einzigen Verbindung 600 Fernsprechkanäle oder ein Fernsehkanal übertragen werden soll. Obwohl andere Modulationsmethoden vielleicht weniger grosse Anforderungen stellen, bleibt doch zu untersuchen, ob die Bereitstellung solch grosser Frequenzspektren selbst bei wichtigen schwer belasteten Weitverkehrssystemen gerechtfertigt ist. Diese Frequenzen müssen in dem Bereich von 1000 bis 10000 MHz gefunden werden, der zur Zeit von vielen anderen Funkdiensten benutzt wird, welche sich selbst auszudehnen gedenken. Der geringe Pegel der Empfangssignale macht eine gemeinsame Benutzung gleicher Frequenzen schwierig und kann zu Störungen führen, besonders weil die Übertragung über Satelliten eine begrenzte Richtwirkung hat und aus diesem Grunde grosse Teile der Erdoberfläche gleichzeitig angestrahlt werden.

Daraus lässt sich der Schluss ziehen, dass Mittel zur Bandbreiteneinschränkung ernsthaft untersucht werden müssen, wenn der Weitverkehr über Satelliten bei gleichzeitiger Benutzung anderer Systeme nicht innerhalb weniger Jahre nach seiner Einführung bereits abgewürgt werden soll. Diese Technik der Bandbreiteneinsparung hat in den letzten Jahren nicht die Aufmerksamkeit gefunden, welche durch die sich ergebenden Vorteile gerechtfertigt erscheint. Dies ist wahrscheinlich einer der wichtigsten Lösungswege, die im Hinblick auf eine in dem nächsten Jahrzehnt erforderliche schnelle Ausweitung der Fernsprech-Verkehrskapazität noch untersucht werden müssen. Es besteht überhaupt kein Zweifel, dass Satelliten-Weitverkehrssysteme durchführbar sind und dass ihre Wirtschaftlichkeit in einem günstigen Verhältnis zu anderen Weitverkehrssystemen steht.

Wenn der Satelliten-Weitverkehr voll ausgenutzt werden soll, dann ist eine sofortige gemeinsame Arbeit der Regierungen, der Betriebsgesellschaften und der Hersteller von grosser Wichtigkeit. Für die Unterstützung von duplizierten Forschungsprojekten oder für internationale Konkurrenz steht keine Zeit mehr zur Verfügung. Ein geplantes Programm muss aufgestellt werden, in welchem niedergelegt ist, welche Projekte die günstigsten sind und welche Zeiteinteilung gewählt werden muss. Die gleichen Überlegungen beziehen sich zweifellos auch auf die Abfeuerung von Raketen und Satellitenkörpern.

Dies ist kein Problem für nur ein Land oder nur einen Kontinent. In den letzten Jahren wurde die internationale Zusammenarbeit unter Schwierigkeiten aufgebaut und diese Zusammenarbeit muss voll angewendet werden.

SEITE 18

DIE FERNÜBERTRAGUNG VON RADARINFORMATIONEN

Weitbereich-Rundsicht-Radaranlagen sowohl für zivile als auch militärische Zwecke werden normalerweise dort aufgestellt, wo sich die beste Radarerfassung erzielen lässt. Diese Stellungen liegen oft in einiger Entfernung von den Betriebszentralen, in denen die Radarinformationen benötigt werden. Zu diesem Zweck müssen Mittel zur Übertragung der Radarsignale mit grösster Genauigkeit und Schnelligkeit zwischen diesen Zentralen vorgesehen werden. Radarsignale sind ihrer Natur nach breitbandig und obwohl verschiedene Methoden für Bandbreiten-Kompression zur Übertragung der Informationen über Fernsprechleitungen oder schmalbandige Kanäle entwickelt wurden, haben diese Methoden verschiedene Nachteile in technischer und wirtschaftlicher Hinsicht. Durch eine Benutzung der Mikrowellenfrequenzen lässt sich jedoch die für direkte Übertragung der breitbandigen Radarsignale erforderliche Kanalbreite leicht beschaffen. Eine ausgiebige Benutzung von Wanderfeldröhren in den Hochfrequenzteilen dieser Anlagen verbessert sowohl die Einfachheit als auch die Zuverlässigkeit.

Eine typische Breitband-Mikrowellen-Radarverbindung (Abb.3) kann folgende Informationen gleichzeitig übertragen: Zwei Kanäle für Videosignale von Primär-Radaranlagen, einen Kanal für Signale von Sekundär-Radaranlagen, einen oder mehrere Kanäle für Radarantennen-Winkelwertübertragung und verschiedene weitere Signale, wie die Fernübertragung von Informationen über die Arbeitsweise der Radargeräte und Sprachkanäle. Alle diese Signale werden in einem Basisband von ungefähr 9MHz Breite zusammengefasst. Dieses Basisband dient dann zur Frequenzmodulation eines Hochfrequenzträgers in dem 4000MHz Band.

Eine rückwärtige Verbindnung für eine viel geringere Bandbreite kann in dem System vorgesehen werden und für die Übertragung von Steuerfunktionen und Rückruf-Sprachkanälen von der Betriebszentrale zu der Radarstellung hin benutzt werden. Ein Blockschaltbild der gesamten Einrichtung wird in den Abb.1 und 2 gezeigt.

Eine rückwärtige Verbindung für eine viel Civil Aviation Administration' in Wellington eingebaut worden. Das Radargerät befindet sich auf einem Berggipfel oberhalb der Stadt und eine Breitband-Richtfunkverbindung im 4000MHz Band überträgt die Radarsignale über ein doppeltes Antennensystem sowohl zu dem Flugsicherungsamt in Wellington selbst als auch zu dem Flughafen Rongotai, der einige Meilen entfernt liegt. Eine Rückrufverbindung wird zwischen dem Flugsicherungsamt und der Radarstellung betrieben. Da die Endstelle in Wellington keine direkte Sichtverbindung mit der Radarstellung hat, werden die Signale in beiden Richtungen mittels eines grossen Spiegelreflektors umgelenkt, der sich auf einem Hügel befindet, welcher von beiden Endstellen aus sichtbar ist. Eine Luftaufnahme (Abb.4) zeigt Einzelheiten des Verbindungsweges.

SEITE 28

FUNKFERNSPRECH-ENDSTELLEN

von B. W. Bardwell

Fernsprechverbindungen für den Kurzwellen-Weitverkehr unterliegen den Launen der Ausbreitung durch die Ionosphäre und benötigen aus diesem Grunde besondere Steuer- und Überwachungsschaltungen, insbesondere seitdem die Übertragungsmethode mit unabhängigen Seitenbändern für mehrere Fernsprechkanäle immer zahlreicher angewendet wird. Die Steuerung wird bei den Funksprech-Endstellen durchgeführt.

Die Lage der Funkfernsprech-Endstellen in einer typischen Verbindung ist in Abb.1 gezeigt und im allgemeinen sind ihre Hauptaufgaben folgende:

(1) Eine Verhinderung von Rückkopplungspfeifen.

Theoretisch schützen die Gabelübertrager für die Zweidraht/Vierdraht-Umwandlung, die Verbindungen gegen Rückkopplungspfeifen. Ihre Arbeitsweise unter den beiden kritischen Schaltungsbedingungen ist in Abb.4 wiedergegeben. Dieses Ideal wird in der Praxis nicht erreicht, wo eine Gesamt-Schleifenverstärkung von 30-40dB auftreten kann. Aus diesem Grunde wird ein zusätzlicher Schutz in Form von Rückkopplungssperren benötigt, welche automatisch eine Dämpfung einfügen, bei der der 'Hinweg' blockiert wird, wenn der 'Rückweg' offen ist und umgekehrt (SS 1 und SS 2 in Abb.2). Abb.5 zeigt die Grundschaltung einer Rückkopplungssperre, während in Abb.6 eine Sperrschaltung hinzugefügt ist, die ein Ansprechen der Rückkopplungssperren auf Sprachströme und Rauschen verhindern soll, wenn diese Spannungen oder Ströme aus dem Rückweg über die Gabelübertragung in den Hinweg gelangen. Abb.7 enthält als weiteren Zusatz eine Differentialschaltung, die zwischen Sprache und Rauschen unterscheidet, wodurch die Verbindung gegen ein durch Rauschen allein verursachtes Rückkopplungspfeifen geschützt wird.

(2) Eine grösstmögliche Verhinderung von Rauschen und Schwund als Folge der Übertragung durch die Ionosphäre.

Durch die Benutzung eines empfangsseitigen Verstärkers mit konstantem Ausgangspegel in einer Funkfernsprech-Endstelle (siehe Abb.2) können schwere Schwunderscheinungen und hohe Rauschpegel erheblich verringert werden.

Ein solcher Verstärker, der in Abb.9 gezeigt wird, reduziert weiterhin die durch Schwund erzeugten Signalpegelschwankungen (dies ist bei Übertragungen mit unabhängigen Seitenbändern von grosser Wichtigkeit, weil die automatische Verstärkungsregelung des Empfängers auf die Gesamt-Pegelschwankungen anspricht). Der Verstärker ist so konstruiert, dass in den Gesprächspausen die Verstärkung gleich null wird.

(3) Eine Normalisierung der Pegel der Teilnehmer-Sprachsignale.

Um das bestmögliche Rauschverhältnis im Empfänger zu erreichen, muss der Sender dauernd voll moduliert werden. Dies wird durch die Benutzung von sendeseitigen Verstärkern mit einem konstanten Ausgangspegel erreicht.

Ausserdem hat die Endstelle eine Reihe von zusätzlichen Funktionen zu erfüllen:

(1) Eine Kanalumsetzung, bei der zwei Känale von 250-3000 Hz zu einem Kanal in dem Band von 250-6000 Hz dadurch vereinigt werden, dass einer der Känale mit einer Frequenz von 6,25 kHz gemischt wird. Die kombinierten Känale können zur Modulation eines Seitenbandes bei Verbindungswegen mit unabhängigem Seitenbandbetrieb benutzt werden. Die Kanal-Rückumsetzung ist ein umgekehrter Vorgang, bei dem die gleiche Umsatzfrequenz benutzt wird.

(2) Geheimhaltung, entweder durch Benutzung einer einfachen Inversion oder durch Aufteilung des Sprachbandes in 5 nebeneinander liegende Teilbänder und deren Vertauschung mit gleichzeitiger Inversion einiger Teilbänder in vereinbarten Kombinationen (Abb.11 und 12).

(3) Kompander können gelegentlich benutzt werden, um den auf dem Funkweg entstehenden Rauschpegel in bezug auf schwache Signale zu reduzieren. Das Gesamtergebnis ist eine Verbesserung des Rauschverhältnisses bei subjektiver Beurteilung. Dabei muss berücksichtigt werden, dass diese Verbesserung nur in den Pausen zwischen den Silben erreicht wird (siehe Abb.13).

Wegen der Natur der Kurzwellen-Funkfernsprechverbindungen muss die Bedienung und Steuerung durch technisches Personal von Hand durchgeführt werden, wobei dieses Personal mit dem Fernsprech-Vermittlungsbeamten über eine direkte Leitung verbunden ist. Bei schlechten Übertragungsbedingungen kann das technische Personal im Notfall die Leitung vollkommen selbst übernehmen.

Funkfernsprech-Endstellenzentralen kann man in groben Zügen in drei Gruppen einteilen:

(1) Weltstadt-Endstellen wie die Endstelle London in Brent, wo die Bedienung von Steuerpulten aus erfolgt, die in einiger Entfernung von den Geräten aufgestellt sind (siehe Abb.15 und 16).

(2) Endstellenzentralen für ungefähr 5 bis 20 Funkverbindungen, bei denen das technische Personal die Endstellengeräte selbst beaufsichtigt. Der grösste Teil der Zentralen in der Welt fällt in diese Gruppe, von der die Station Hongkong der Cable & Wireless Ltd. ein typisches Beispiel ist. (Siehe Abb.17).

(3) Einfache Einzelfunkverbindungen, in denen die Endstelle eine direkte Verbindung zwischen dem Funkweg und etwa 5 Teilnehmern darstellt. Das Bedienungspersonal stellt die Verbindung her und ihm untersteht die technische Aufsicht.

Die grundsätzlichen Aufgaben der Funkfernsprech-Endstelle haben sich in den letzten 20 Jahren kaum verändert. Bei der neuerlichen Einführung von Transistoren und gedruckten Schaltungen lassen sich die Grösse und der Stromverbrauch der Geräte beträchtlich vermindern (siehe Abb.18). Eine Modul-Bauform wird dadurch möglich (siehe Abb.20) und verkleinert die Wartungsprobleme beträchtlich.

Zwei Wege zur Verbesserung der Kurzwellenverbindungen und zur Verringerung der benötigten Bandbreite müssen noch weiter untersucht werden, und zwar:

(1) Durch Einführung einer automatischen Sprachverschachtelung auf der Basis der Zeitstaffelung (ein Sprecher spricht normalerweise nur während 40% der Gesprächsdauer), bei der ein Silbendetektor benutzt wird. Dies ist als das TASI-System (Time Assignment Speech Interpolation = zeitgestaffelte Sprachverschachtelung) bekannt. Obwohl dieses System zur Zeit nur auf Kabelverbindungen benutzt wird (wo es die Kanalkapazität verdoppelt hat) kann dieses Prinzip möglicherweise auch auf Hochleistungs-Kurzwellenverbindungen angewendet werden, wo selbst eine Verbesserung von 25% in der Kanalkapazität lohnend ist.

(2) Durch Ausschaltung der Redundanz in der Sprache, indem nur Stimmschwankungen übertragen werden. Der Sprachinhalt wird durch ein Gerät, wie etwa ein Vocoder (voice-coder), analysiert, wenn der Teilnehmer spricht. Das Ergebnis dieser Analyse wird in verschlüsselter Form über die Verbindung übertragen und am Empfangsende wieder entschlüsselt. Auf diese Weise kann verständliche Sprache mit einem Zehntel der normalerweise benötigten Bandbreite übertragen werden.

Eine weitere Verbesserung des zuletzt genannten Systems scheint sehr vielversprechend zu sein und es scheint möglich zu sein, dass beide Systeme in sich gegenseitig ergänzender Form gleichzeitig angewendet werden können.

Presentamos este sumario de los articulos publicados en este número, redactado en castellano especialmente para nuestros lectores de habla castellana.

PAGINA 3

PUNTOS DE VISTA

El rendimiento total que se obtiene entre dos abonados dados en sistemas telefónicos depende mayormente de factores económicos. Se determina el rendimiento conjuntamente con el abonado y la red de la central telefónica local, que forman el interés más importante de la inversión. La C.C.I.F recomienda que la pérdida total en transmisión quede limitada a 40dB, de los cuales 18dB pueden localizarse en el terminal transmisor; la calidad de los circuitos queda específicamente excluída. El sistema a larga distancia, con ser sólo una pequeña proporción de la totalidad, debe poseer un rendimiento suficientemente bueno como para no desmejorar perceptiblemente el rendimiento total entre abonado y abonado. Con pequeñas cantidades de canales extendidos sobre distancias relativamente cortas, ésto nunca alcanzó a ser un problema serio. Desde que se pudo disponer de enlaces radiotelefónicos multicanales, la tendencia fué hacia la aplicación directa de las normas de rendimiento de líneas alámbricas a la radio, sin tener completamente en cuenta las limitaciones de éste último medio.

A medida que iban extendiéndose las redes internacionales se aumentaron las exigencias técnicas recomendadas para los circuitos a larga distancia. Estas normas están actualmente a un nivel tal que es dudoso si hay alguno de los circuitos principales de línea en Europa que se mantenga a este nivel. En el campo de la radio, pese a los ingentes gastos en desarrollo, recién ahora se empieza a disponer de equipos que cumplen íntegramente las recomendaciones de la C.C.I.R, siendo dudoso que haya suficiente márgen como para permitir la mantención de este rendimiento en forma económica.

Económicamente no es practicable establecer circuitos a dispersión troposférica que cumplan totalmente las normas C.C.I.R. Aún en los cables telefónicos submarinos se está recurriendo al espaciado reducido de los canales y a su uso en común, debido a cuestiones económicas. Cuando se disponga de circuitos que empleen satélites, es sumamente dudoso que los mismos puedan llegar a cumplir las normas de la C.C.I.R.

Las mejoras en los aparatos telefónicos y en las redes locales están resultando en una calidad muy superior en la transmisión de la voz, y las pérdidas de circuito para la mayoría de los abonados son mucho menores que el máximo tolerado, 18dB. Una reducción de unos 6dB en las normas de rendimiento de circuitos a larga distancia llevaría a la paridad entre las normas de rendimiento C.C.I.R y las usadas en larga distancia en Norte América, que dan por resultado niveles muy buenos en la red telefónica Bell. Ello facilitaría el diseño, y en modo especial los problemas de la mantención, en grado sumo.

Nos hallamos actualmente en la etapa formativa para equipos que brindarán muchos de los servicios a larga distancia en lo futuro, ya sean circuitos coaxiles con repetidores o bien una de las varias soluciones basadas en la radio. Una revisión de los rendimientos de sistemas establecidos antes de que alguno de dichos medios esté disponible no estaría fuera de lugar, y la misma debería hacerse basándose en las necesidades de la época actual.

PAGINA 6

UNA NOTA ACERCA DE LA COMUNICACION POR SATELITES

por M. Telford

El monopolio virtual de las comunicaciones telefónicas internacionales, ejercido por los servicios de radio a AF está enfrentado firmemente por los sistemas transoceánicos de cables, de banda ancha. Si bien sumamente caros, la elevada capacidad de tráfico y los altos niveles de rendimiento ofrecidos por éstos últimos indican que la mayor parte del tráfico telefónico a larga distancia entre los centros principales pasará a cables coaxiles en los próximos 10 á 20 años. La única alternativa que se vislumbra actualmente consiste en el uso de sistemas de satélites terráqueos. Recientes estudios intensificados de éstos sistemas demuestran que los satélites, pasivos y activos, son una posibilidad; aquél tipo fué demostrado en forma experimental mediante el Proyecto Eco, con un globo reflector. No obstante, aún empleando tranmisores de 10kW y antenas de grandes dimensiones en los dos extremos del enlace, la capacidad de este sistema experimental es sólo un canal oral. Si bien ésta podrá aumentarse, con toda seguridad, las perspectivas de lograr económicamente una gran capacidad para tráfico no son muy prometedoras. Para una relación señal/ruido de 40dB en una banda de base de 5Mc/s, es

menester un transmisor de 100kW y antenas de 150 piés de diámetro en cada terminal. Con un satélite activo se obtendría un resultado comparable irradiando 1W y empleando una antena de 60' en el receptor. Se necesitaría un transmisor de 1kW en tierra, para tener en cuenta el menor rendimiento del receptor satélite que cabría esperarse en dichas condiciones. Puede decirse con toda seguridad que el equipo de radio necesario a un sistema eficiente basado en satélite activo repetidor está dentro del alcance de las técnicas actuales, aunque hay muchos problemas de detalle en su diseño, especialmente los tocantes a la confiabilidad de las piezas componentes, a los que es menester buscarles solución.

La asignación de espacio en el espectro será de importancia primordial. Los cálculos que anteceden presuponen un sistema de FM de amplia desviación que requerirá 250Mc/s de lugar en el espectro para el satélite pasivo ó 500Mc/s para el activo, para un enlace simple que transmita 600 canales de palabra o bien un sólo canal de televisión. A pesar de que con otros sistemas de modulación talvéz se reduzca dicho requerimiento, queda en duda la conveniencia de asignar bloques tan grandes del espectro aún si son para sistemas de comunicaciones de primera importancia, extremamente sobrecargados. Este espacio debe encontrarse en la región entre 1000 y 10000Mc/s, la que se halla ocupada en la actualidad por muchos otros servicios, que tienden a expandirse ellos mismos. El nivel reducido de la recepción dificultará el uso común de frecuencias, pudiendo causar problemas de interferencia, particularmente si se tiene en cuenta que las transmisiones por satélite tendrán una dirección de propagación limitada, por lo que iluminarán simultáneamente a grandes áreas de la tierra.

Es dable llegar a la conclusión que deben buscarse de forma intensiva las medidas para economizar amplitud de banda si los sistemas de comunicación por satélites, junto a otros servicios, han de salvarse del ahogo a los pocos años de su entrada en servicio. Estas técnicas no han merecido la atención —justificable por los beneficios que rendirían— en años recientes, y ésta es casi seguramente la zona más importante que queda por explorar en la tarea de conseguir la rápida expansión de la capacidad para tráfico telefónico que se necesitará en la década entrante. Sin duda alguna los sistemas de comunicaciones por satélites son realizables, y asimismo económicamente serán comparables ventajosamente con los sistemas alternativos usados en largas distancias.

Si las posibilidades de la comunicación por satélites han de explotarse al máximo, se hace imprescindible un esfuerzo concertado por parte de los gobiernos, las compañías de explotación de servicios y los fabricantes de equipos. No hay tiempo para permitir la realización de proyectos de investigaciones paralelos ni para la competencia internacional en la materia. Debe establecerse un programa planificado que determine cuáles son los proyectos más favorables y las fechas de su realización. Las mismas consideraciones valen, a no dudarlo, para el lanzamiento de cohetes dirigidos y vehículos satélites.

Este no es problema de sólo una nación o un continente. La organización para la colaboración internacional se ha cimentado no sin dificultades en los últimos años y se la debe aprovechar al máximo.

PAGINA 18

PRESENTACION REMOTA DE INFORMACION RADAR

Los radares de vigilancia a largo alcance tanto de uso civil como militar se ubican generalmente en sitios desde los cuales están en condiciones de ofrecer una óptima cubertura. Estos sitios a menudo están muy alejados de los centros de operaciones donde se requiere la información radar, debiéndose por tanto proveer medios para transmitir las señales radar a estos centros de la manera más exacta y rápida que sea posible. Las señales de radar son necesariamente de banda ancha, y a pesar de que se han desarrollado varios métodos de compresión de bandas anchas, a fin de permitir la transmisión de dicha información por líneas telefónicas o por canales de radio de banda angosta, estos métodos padecen varias desventajas técnico-económicas. No obstante, mediante el empleo de bandas de frecuencias micro-onda se consiguen fácilmente los canales necesarios para la transmisión directa de señales radar de banda ancha; el uso generalizado de tubos de ondas circulantes o progresivas en los elementos radiofrecuentes de los equipos redunda en la sencillez y la confiabilidad de los mismos.

Un enlace típico de radar en micro-onda, de banda ancha (Fig.3), puede llevar simultáneamente dos canales de señales video de radar primario, un canal de señales de radar secundario, uno ó más

canales con datos sobre rotación de antenas radar y varias señales auxiliares, tales como información telemedida sobre el comportamiento del radar y canales orales. Estos se combinan en una banda de base de unos 9Mc/s de amplitud, que luego se modula en frecuencia en la portadora radiofrecuente, en la banda de 4000Mc/s.

Es posible incorporar al sistema un enlace de retorno en una banda mucho más angosta, para transmitir por él datos de control de funcionamiento y canales orales de retorno desde el centro de operaciones al puesto remoto del radar. En las Figs.1 y 2 se ilustra en forma de diagrama un sistema completo de este tipo.

Un sistema como el que se describe ha sido instalado por la Administración de la Aviación Civil de Nueva Zelandia, en la ciudad de Wellington. El radar está emplazado en una montaña que mira sobre la ciudad, y un enlace de banda ancha a 4000 Mc/s envía las señales radar por medio de un sistema de antenas gemelas al Centro de Control de Tráfico Aéreo en Wellington mismo y al aeropuerto local de Rongotai, ubicado a unos kilómetros de distancia. Hay un enlace de retorno entre el Centro de Control y el puesto de radar. Puesto que el terminal de Wellington no está en la línea de mira del puesto de radar, las señales en ambas direcciones son transmitidas mediante un gran reflector en forma de plato, que se encuentra en una colina que mira sobre los dos terminales. La fotografía aérea (Fig.4) muestra en detalle la senda de este enlace.

PAGINA 28

EL TERMINAL RADIOTELEFONICO

por B. W. Bardwell

Los circuitos radiotelefónicos a AF sobre grandes distancias están supeditados a las extravagancias de la propagación por lo que requiren un control y una supervisión especiales de los circuitos mismos, particularmente en virtud de que las transmisiones en banda lateral independiente, portadoras de varios canales telefónicos, se van haciendo mas numerosas. Dicho control se realiza mediante el terminal radiotelefónico.

La ubicación del terminal radiotelefónico en un circuito típico queda ilustrada en la Fig.1; a grandes razgos, sus funciones principales son las siguientes:

(1) Ofrecer protección contra la inestabilidad de los circuitos metálicos producida por la realimentación.

Teóricamente, los transformadores diferenciales que permiten la transformación de bifilar a tetrafilar deberían protejer al circuito contra la inestabilidad del bucle; en la Fig.4 se ilustran sus funciones en dos condiciones circuitales críticas. Este ideal no se alcanza en la práctica, pudiendo ocurrir en cambio una ganancia neta de 30-40dB en el bucle. Es por ello que se precisa una protección adicional, en forma de supresores de reacción, que automáticamente introducen atenuación de una forma tal que la senda de 'ida' queda bloqueada al hallarse abierta la senda de 'vuelta', y viceversa (SS 1 y SS 2 en la Fig.2). La figura 5 ilustra al circuito básico de un supresor de reacción, la Fig.6, el agregado de un circuito de enclavamiento que impide la operación de los supresores de reacción por la voz y las pérdidas de ruido de la senda de 'vuelta' a la de 'ida' por medio del diferencial, y la Fig.7 otro agregado más, un equilibrio diferencial que discrimina entre la voz y el ruido, protegiendo al sistema contra la inestabilidad derivada del ruido solamente.

(2) Contrarrestar en la medida posible el ruido y el desvanecimiento debidos a la propagación por la ionosfera.

El desvanecimiento pronunciado y los altos niveles de ruido se reducen considerablemente con el empleo de un amplificador de recepción a volúmen constante en la senda de 'retorno' del terminal radiotelefónico (ver Fig.2). Este tipo de amplificador, ilustrado en la Fig.9, reduce asimismo a las variaciones del nivel de la señal debidas al desvanecimiento (ello reviste importancia especial en las transmisiones de BLI, en las que el CAS del receptor actúa en las fluctuaciones totales del nivel de señal). El mismo está proyectado para una ganacia cero en los intervalos entre pasajes de la voz.

(3) Normalizar los niveles de las señales de palabra de los abonados.

Para asegurar un relación máxima señal/ruido en el receptor, el transmisor debe operar continuamente en condiciones de modulación total. Ello se logra con el empleo de un amplificador de transmisión a volúmen constante.

Por otra parte, el terminal realiza varias tareas subsidiarias:

(1) Desplazamiento de canal, con la cual se combinan dos canales de 250-3000c/s en una banda de 250-6000c/s, desplazando a uno de los canales mediante un oscilador de 6,25Kc/s. Los

canales combinados de esta manera pueden usarse para cargar a una banda lateral de una transmisión en banda lateral independiente. La restauración de los canales es un proceso recíproco que se sirve del mismo oscilador.

(2) El secreto, que se obtiene con la simple inversión o bien dividiendo a la banda de la voz en cinco sub-bandas adyacentes y mezclándolas e invirtiendo a algunas de ellas en combinaciones preestablecidas (Figs.11 y 12).

(3) En ciertos casos pueden usarse compresores/expansores para disminuir el nivel del ruido introducido en la senda de radio, en relación a las señales débiles. El resultado total es una mejora de la relación señal/ruido tal como se oye, pero es menester recordar que dicha mejora vale solamente para los intervalos entre sílabas de la palabra (ver Fig.13).

Debido a la naturaleza misma de los circuitos radiotelefónicos a AF, su operación y control han de realizarse manualmente, por un operador técnico, el que se mantiene en contacto estrecho con el operador de la central telefónica mediante una línea directa. En el caso, puede asumir cargo total de la operación cuando las condiciones del circuito son malas.

Los centros de terminales radiotelefónicos pueden clasificarse en tres grupos generales, a saber:

(1) Los terminales de grandes centros mundiales, como ser el terminal de Londres, situado en Brent, en que el control se realiza mediante consolas de control remoto, alejadas del equipo. (Ver Figs.15 y 16.)

(2) Los centros de terminales que trabajan con unos 5 á 20 circuitos de radio, en que los operadores técnicos realizan la supervisión en los mismos puestos terminales. La mayor parte de los centros mundiales están en este grupo; la estación de Cable & Wireless Ltd. en Hong Kong es un ejemplo típico del mismo. (Ver Fig.17.)

(3) Los sistemas sencillos de senda radial única, en que el terminal dá conexión directa con el circuito de radio a unos cinco abonados. El operador conecta las llamadas y realiza la vigilancia técnica.

Las funciones básicas de los terminales radiotelefónicos han cambiado muy poco en los últimos veinte años, pero con la reciente llegada de transistores y circuitos impresos es dable reducir notablemente el tamaño y el consumo de poder de los equipos (ver Fig.18). Con ellos resulta factible el empleo de la técnica de construcción en subunidades (ver Fig.19), reduciendo notablemente los problemas del servicio.

Continúa el estudio de dos maneras de mejorar a los circuitos de AF y de reducir la amplitud de la banda ocupada por los mismos:

(1) Intercalando automáticamente las conversaciones, en razón del tiempo, mediante un detector de sílabas (el abonado normalmente habla durante sólo un 40% del tiempo que dura su llamada). Esto se denomina Sistema TASI, 'Time Assignment Speech Interpolation' (Interpolación de Palabras por Asignación de Tiempo). Aunque en la actualidad se lo emplea sólo en circuitos por cable (en los que ha doblado la capacidad), el método bien puede tener aplicación en circuitos de AF de elevado mérito, en los que aún un aumento del 25% de la capacidad de los canales sería ventajoso.

(2) Eliminando las redundancies de la palabra, transmitiéndose solamente las fluctuaciones de la voz. Los datos son analizados por un dispositivo tal como el vocoder (codificador de la voz) durante la conversación del abonado. Los resultados del análisis son transmitidos por el enlace en forma de código, el que luego se reconstituye en el terminal receptor. De esta manera es posible transmitir la palabra de forma inteligible en un décimo del ancho de banda que normalmente sería necesario.

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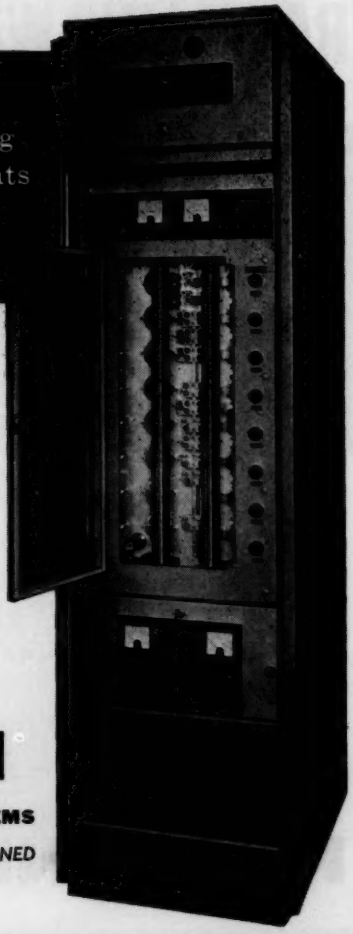

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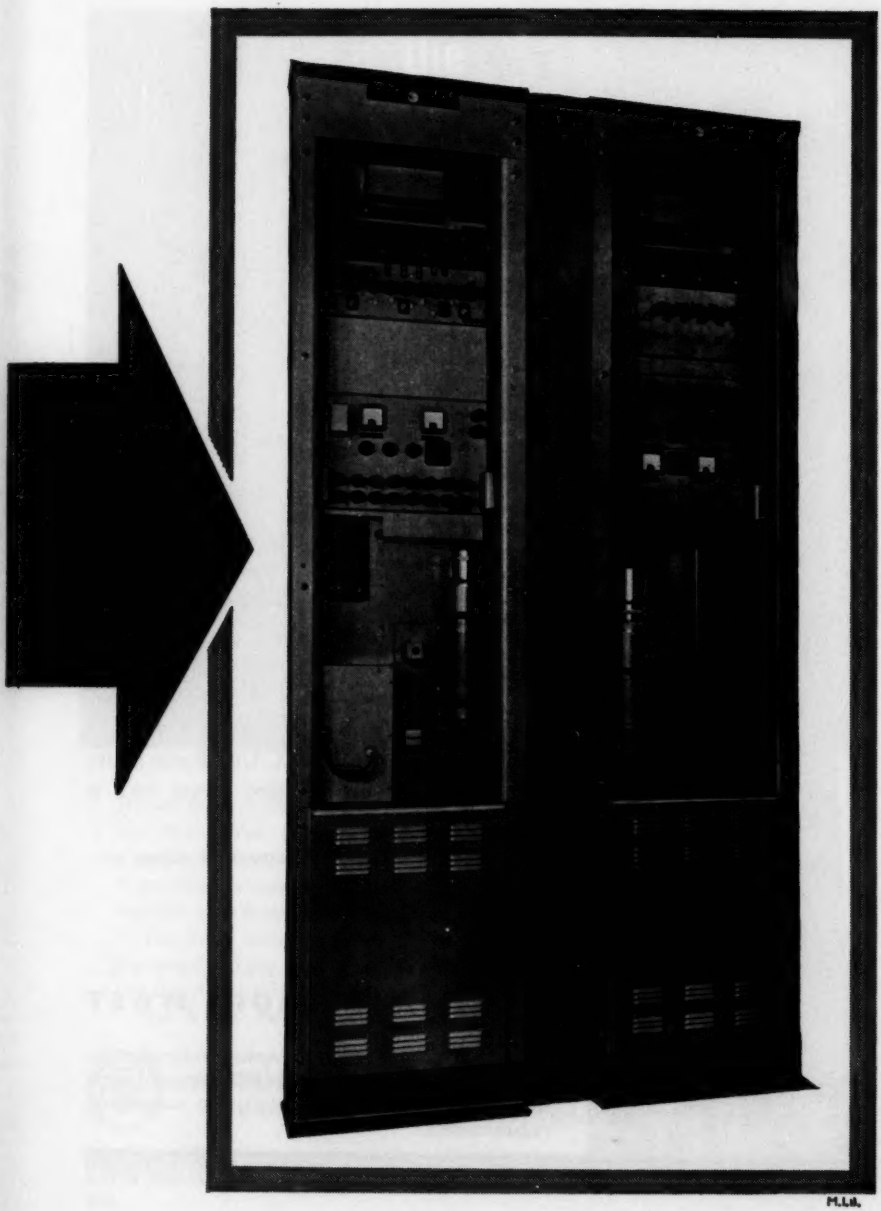

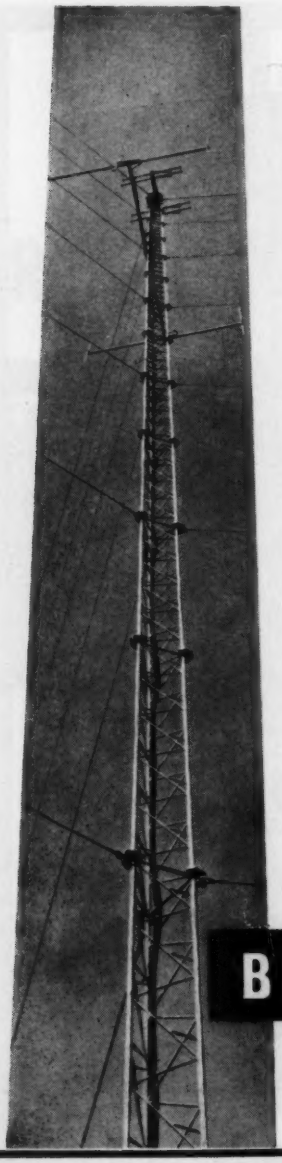

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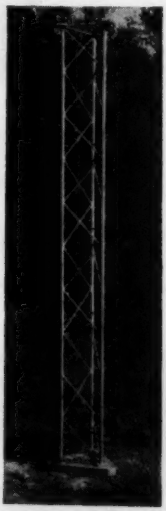

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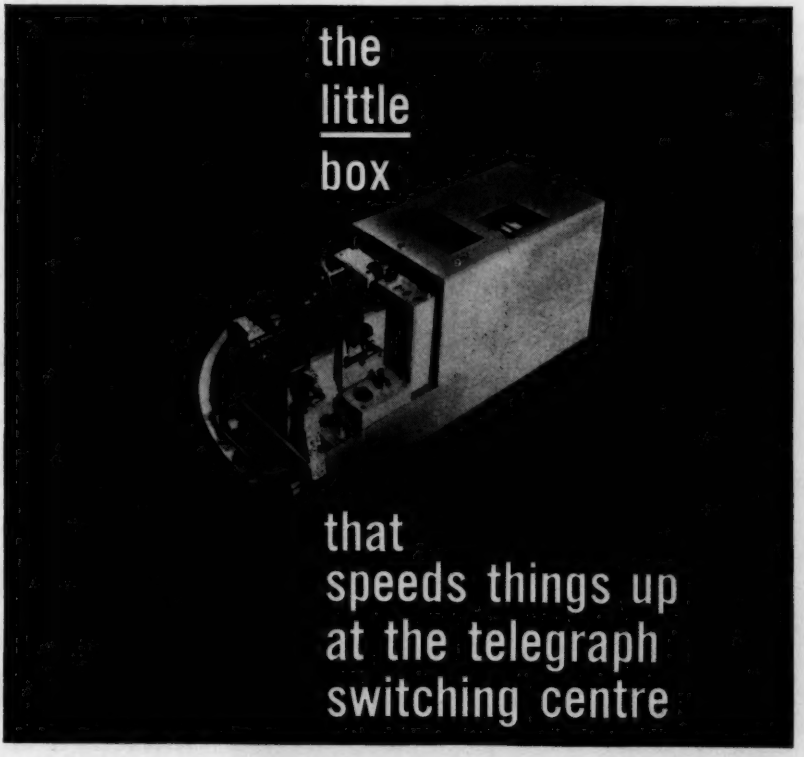

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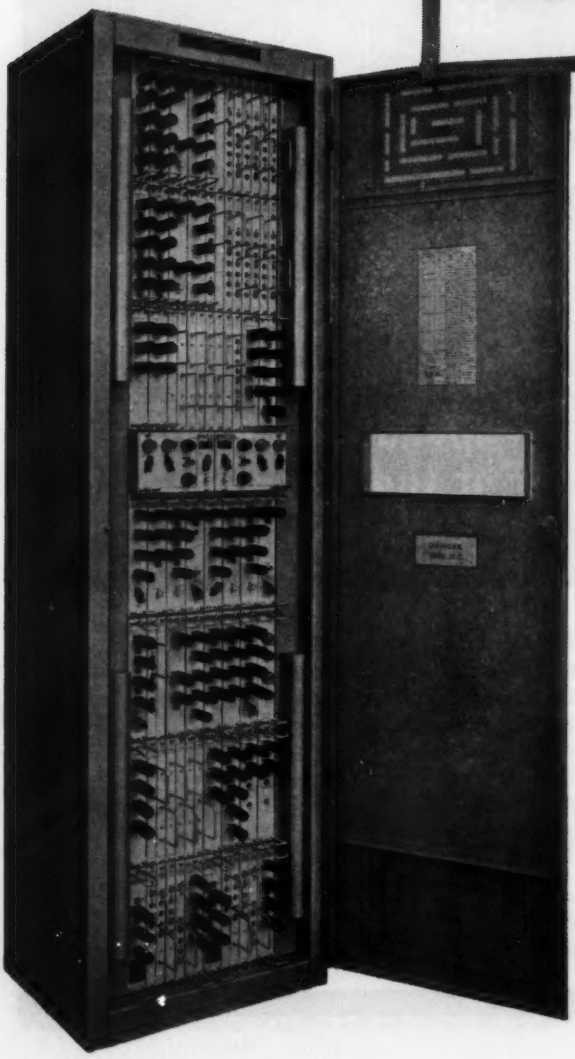
AT 1403i

MARCONI AUTOPLEX



Automatic Error Detection and Correction

TESTED RQ

Each repetition cycle is inspected for the RQ signal and if this is not recognised the repetition is ignored and requested again. This prevents reception of false information during repetitions.

AUTO-PHASING

Automatic phase detection and correction to 'tested RQ' condition on all channels.

seven unit code system

TRAFFIC STORE
Characters stored in channel stores as opposed to common store. Capacity two, three or four characters selectable, permitting operation over long and short circuits.

CONTINUOUS IDLE ALPHA
and Idle Beta facility for initial testing and setting up.

SYNCHRONISING
Synchronising by 1% steps examining every transition. The circuit incorporates an integrator to prevent spurious operation due to multipath. Small synchronising steps result in excellent margins.

For one-way circuits, error indication provided as alternative to ARQ.

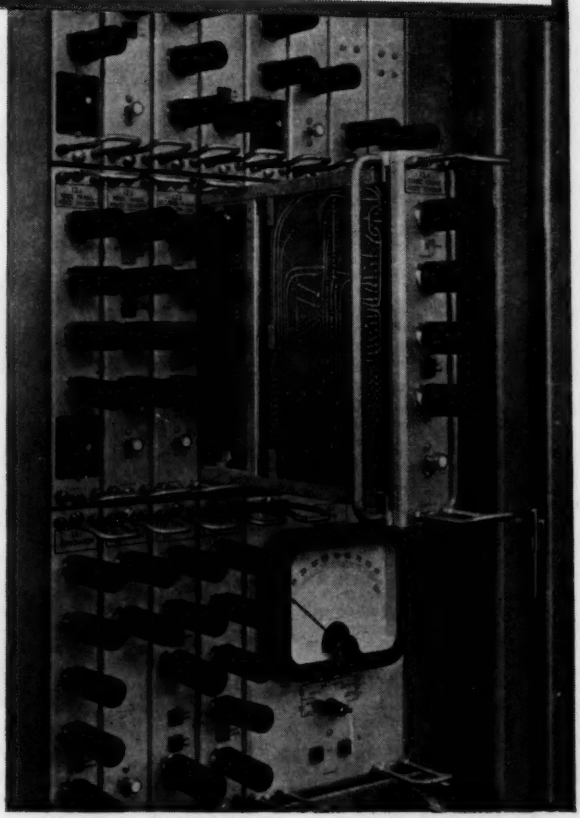
Two-channel or four-channel operation by switch selection.

Single alpha rejection protects against false telex 'clear'.

Coder and Decoder all decode/recode type and entirely passive networks.

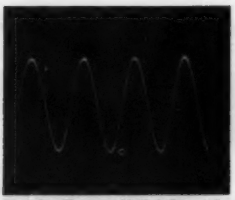
Liberal test points permit every circuit to be examined in traffic conditions.

Frequency Division by counters provides 86, 96 and 100 bauds.

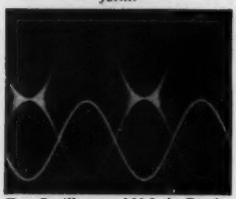


AUTOPLEX A NEW WORD IN COMMUNICATIONS

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND



Test Oscillogram 15 Kc/s Unmodulated Carrier showing good waveform.



Test Oscillogram 320 kc/s Carrier modulated at 400 c/s—audio source on lower trace shows fidelity.

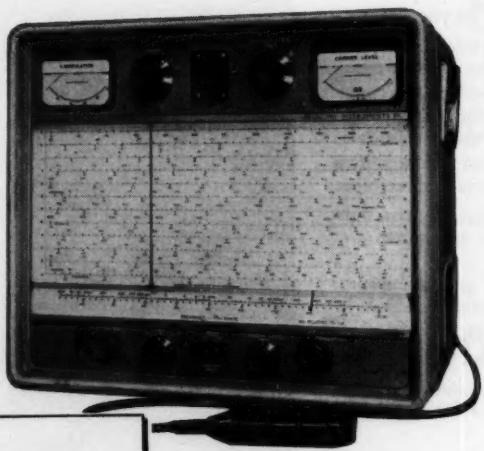
MARCONI

Standard Signal Generator

TYPE TF 867

UNDISTORTED 100% MODULATION

AM WITHOUT FM



WIDE RANGE
15 kc/s to 30 Mc/s on 15 ft. high-discrimination full-vision scale.

CRYSTAL ACCURACY
0.01% with built-in 1 Mc/s harmonic source.

HIGH OUTPUT
4 volts down to 0.4 microvolts.

FLEXIBLE MODULATION
Internal 400 and 1,000 c/s; external 50-10,000 c/s within 1 dB.

Also incorporated: Automatic level control, overall negative feed-back from r.f. output to modulation input, modulation monitoring by dual rectification, and variable impedance termination with animated diagram.

MARCONI INSTRUMENTS

A signal generator also ideal as a video oscillator for wide-band television systems.

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTFORDSHIRE
TELEPHONE: ST. ALBANS 56161
WORLD-WIDE REPRESENTATION

TC 107R